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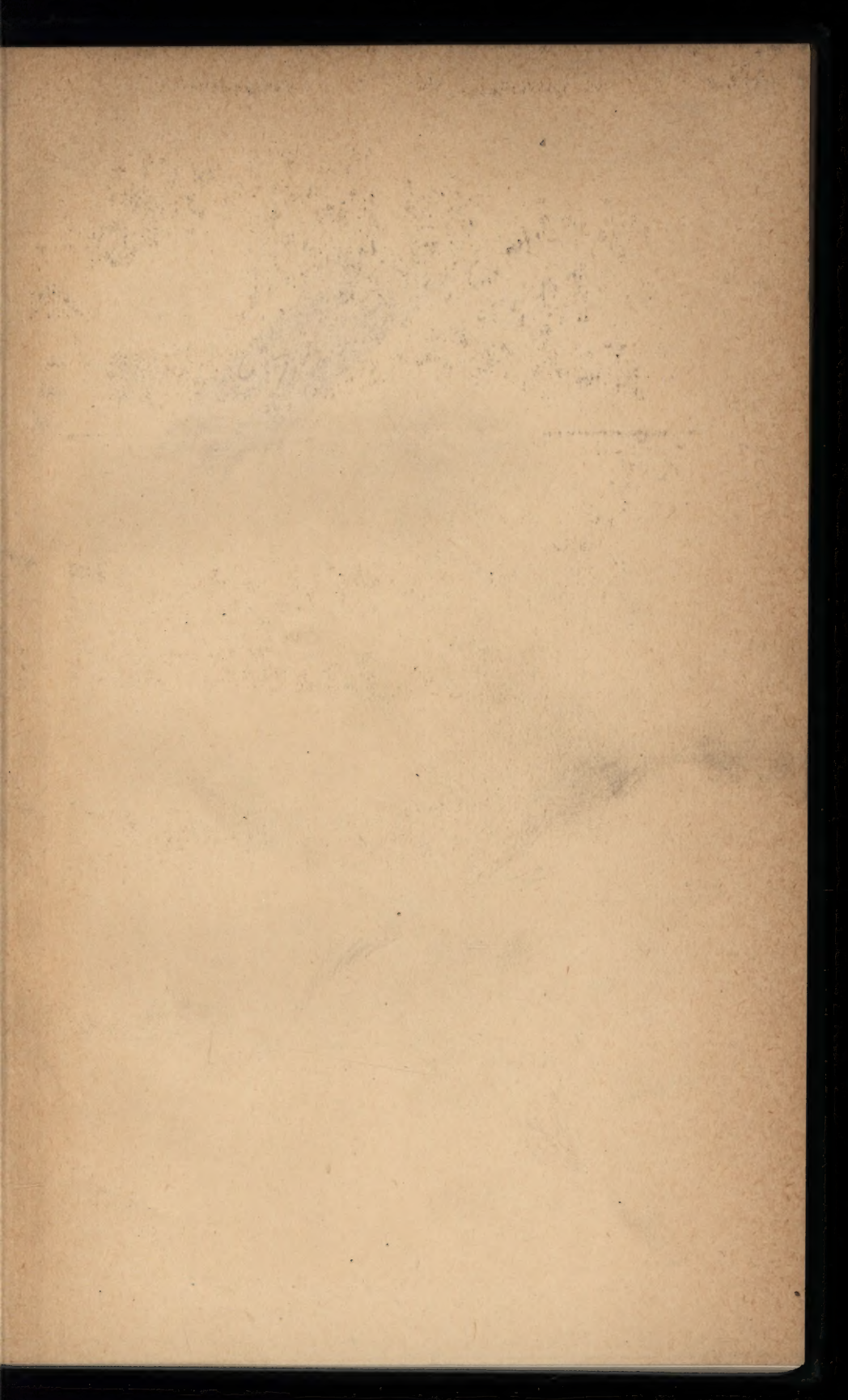
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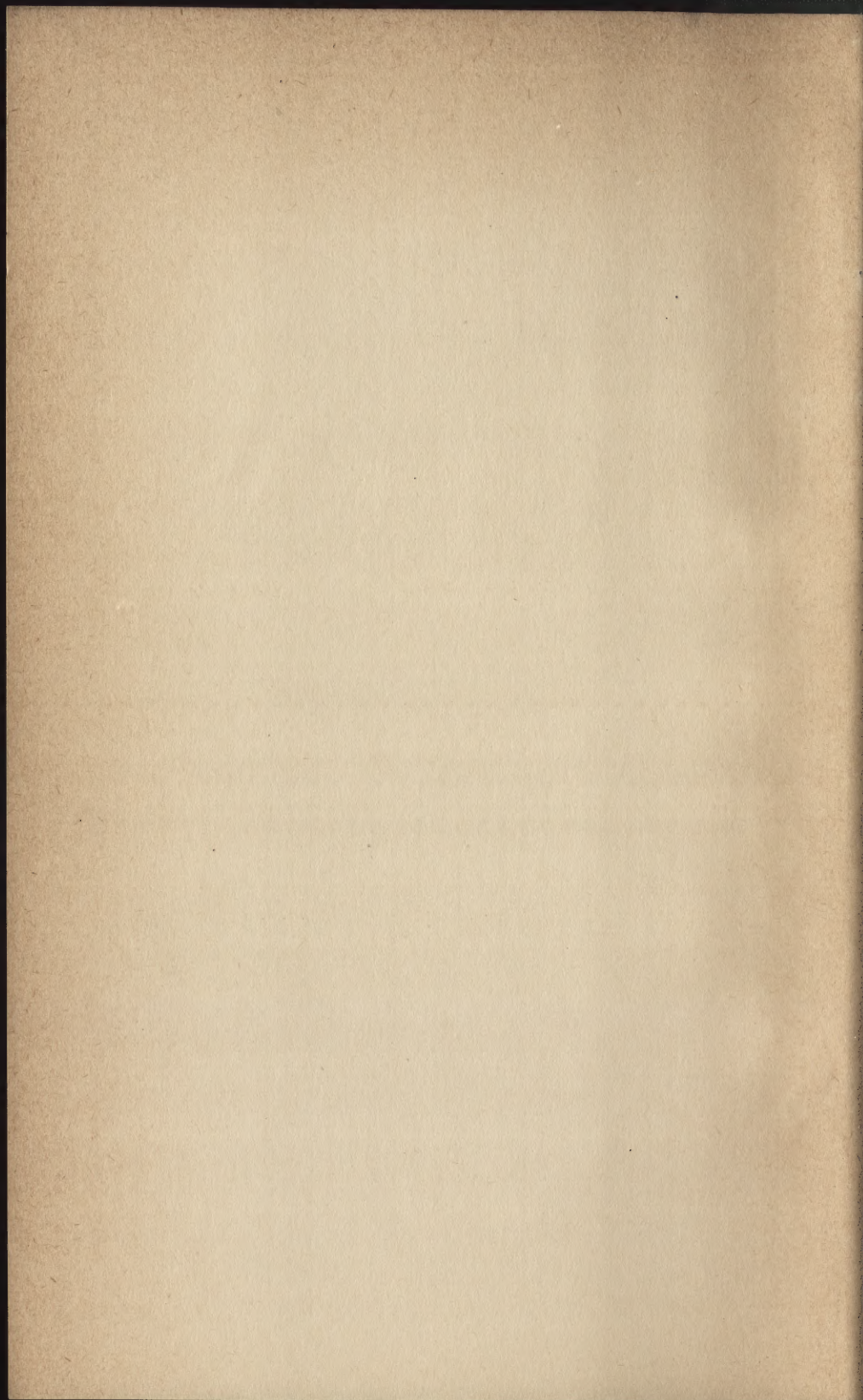
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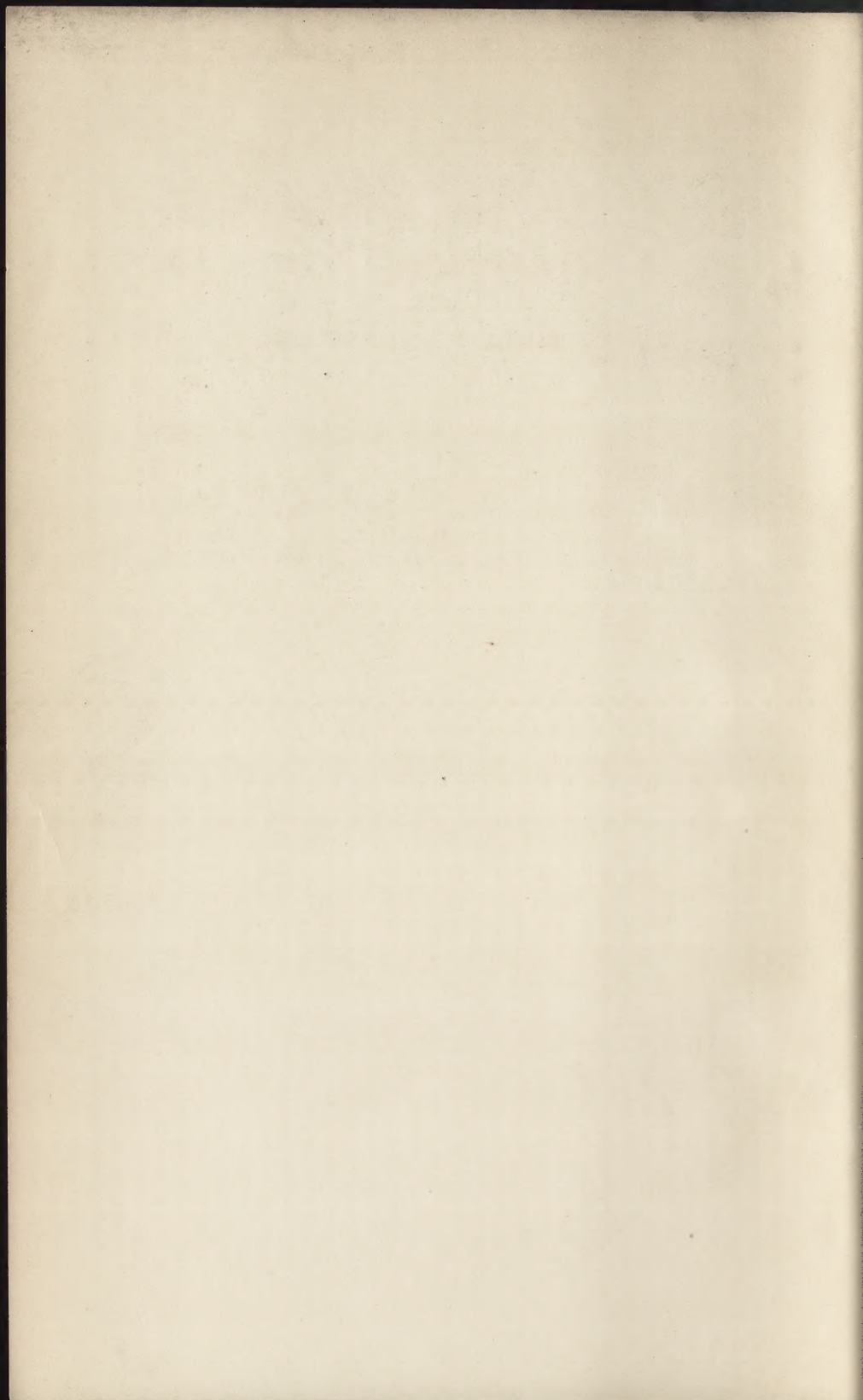
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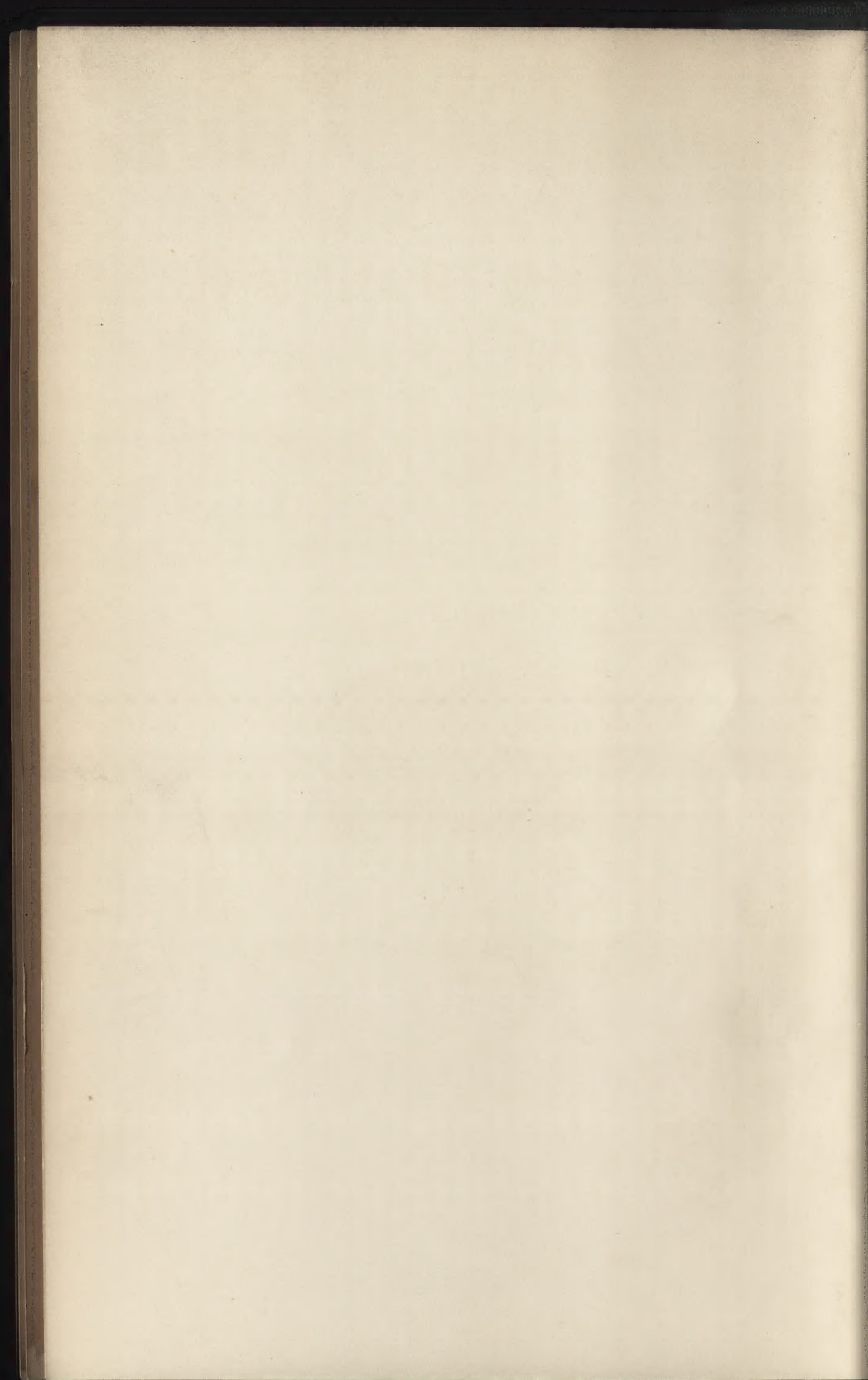
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PRINCIPLES OF
WOOLLEN SPINNING



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PRINCIPLES OF WOOLLEN SPINNING

BY
HOWARD PRIESTMAN

AUTHOR OF
"PRINCIPLES OF WOOL-COMBING" AND "PRINCIPLES OF WORSTED SPINNING"



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VIRGIL J. JARVIS
JANUARY

PREFACE

THE enormous extent and great diversity of the woollen trade make it quite impossible for any one man to be thoroughly acquainted with all its branches. For this simple reason it is impossible for any book to treat in detail of every feature of the trade. Any writer who attempted such a task would have to travel widely. He would spend his life collecting information, and at the end he would be so conscious of the magnitude of the task, that it would probably be left incomplete.

This is my only excuse for publishing the information which has come under my own immediate observation in the last few years. I am well aware that specialists will be able to point to omissions, but particulars regarding many branches of the woollen trade are so scarce in literature that a demand may well exist for such a work as this.

So far as I can ascertain, no book has treated in detail of the shoddy trade since Jubb wrote in 1860, and it is quite needless to point out how much things have altered since that day. In some textile books the process of carbonizing has been described as an injurious system that should certainly be eliminated, and details of the more modern methods are difficult to find, although they should be very widely known. Such literature as exists regarding the woollen mule is either imperfectly illustrated, or is too technical to be of much

service to the student. It is, therefore, my ambition to remedy these defects.

It is obvious at first sight that the nature of various processes differs widely in different parts of the country. The same results may be obtained by very different means, and it is for this reason that I have invariably laid more stress on the principles involved, than on the facts and figures that are necessary to illustrate them. My work in Huddersfield has naturally influenced my views, but my experience in Ossett and the West of England has modified any inclination to be too dogmatic.

There is probably no trade in the world where the successful man must be more liberal in his views, and more elastic in his methods. He must be prepared for any eventuality, and be prepared also to treat widely differing types of wool by widely differing methods. It is a trade where those who use their brains will inevitably have the advantage over those who still work by rule of thumb.

The writer has always held very strongly that bare facts and figures are of very little use for technical instruction. No better illustration of this view could be found than in the woollen trade, and unless a reader understands the reasons that underlie the facts, he will gain little by his knowledge of them. It is with the twofold object of stating facts and then explaining them that this book is written. In the first place, it gives facts and figures that have hitherto been very difficult to find, and in the second it supplies the reasons for the great diversity in the methods that may be found in various places where woollen yarns are spun.

It will be noticed by most practical men that no reference is made to Frame or Throstle spinning. The reasons for the

omission are twofold. In the first place, I have endeavoured to confine my descriptions to machinery that has come under my own observation. Unfortunately these frames are so scarce in this country that I have never yet seen one in regular employment. Whatever may be the case on the Continent, they seem to be only imperfectly understood in England. Secondly, I am told that the methods adopted in working them are likely to be altered in the immediate future. I therefore acted on the best advice I could get and left the subject untouched, preferring rather to leave something out, than to make any statements of doubtful value.

It is customary to close a preface with the names of those persons to whom the writer is indebted for assistance. A mere enumeration of names would be altogether inadequate in the present case, because there is one man without whose assistance the work could hardly have been carried out.

I would very gladly have associated the name of Mr. J. F. Siddle with my own on the title-page of this book, could I have obtained his consent. It is through his courtesy alone that I have had a long practical acquaintance with both English and foreign carding systems. He also gave a great deal of valuable information; his one hope being that he might add some little to the prosperity of his native town, if it were published.

All that is practical in the chapter on Shoddy has been supplied by Mr. J. W. Smith, of Ossett. He not only gave me the free run of his large factory, but in the most generous manner he supplied particulars, not only of his methods and his qualities, but also of the sizes, the setting, and the speeds of his machines. Coming as the information does from such a quarter, it is unnecessary to say anything as to its

authenticity, for Mr. Smith was also good enough to revise the chapter before it was printed.

For much information relating to their well-known machinery, and for the loan and use of drawings, I am indebted to Messrs. Wm. Whiteley & Co., Ltd., of Lockwood. They were also kind enough to let me watch the construction of one of their mules of the type I selected for description, on account of its simplicity and deserved popularity.

The illustration of the Josephy cards are copied direct from drawings lent by Messrs. Newman & Son, of Huddersfield, who were also kind enough to supply complete specifications of the clothing best suited for different types of their machinery. Without these illustrations and figures the book would have been of much less interest, for they show the salient points of continental practice in comparison with those of the home trade.

Messrs. Samuel Law & Sons, Ltd., were kind enough to work out for me the particulars of card clothing, suitable for the enormous engines in use in the shoddy trade, and as there appears to be no reference to these machines in any book in print, the information is of unusual interest. It is, moreover, absolutely up to date.

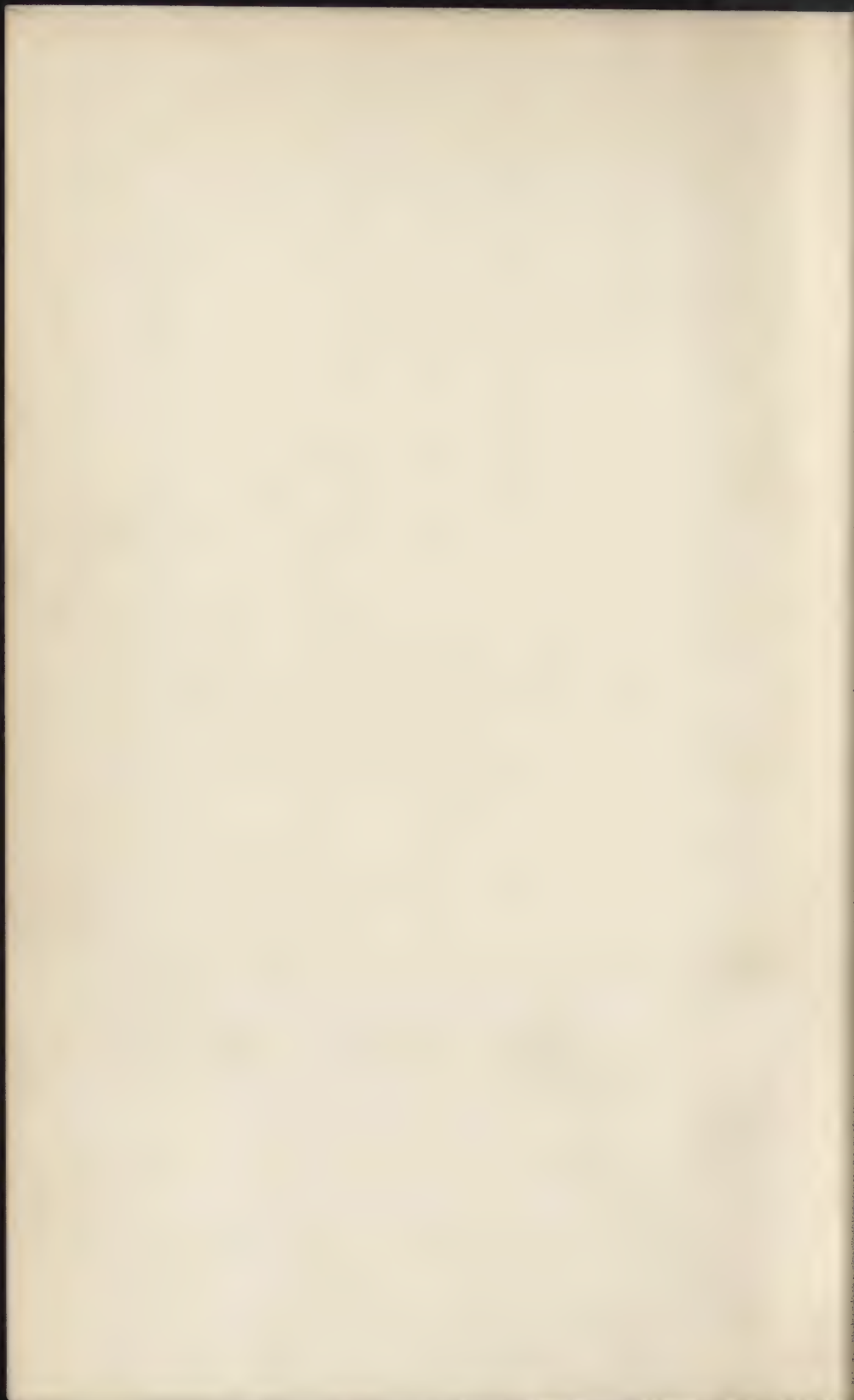
I am also indebted to Professor Clapham, of the Leeds University, for directing my researches in regard to the facts and figures relating to shoddy and its production. All of them are from Blue Books in the University library; but had it not been for his wide knowledge of the sources of information, the figures would have been as inaccessible to me as to the average technical reader. My thanks are also due to Professor Barker, of the Technical College, Bradford, for direction in regard to various departments of the industry, and especially for the

information referred to in the first chapter, and to Mr. Apperley, of Stroud, for facts relating to West of England methods.

The majority of the illustrations are line drawings, which should be regarded rather as diagrams than scale drawings. Many are really sketches made direct from the various machines with the single object of illustrating some particular point. Measurements were nearly always made, but in all cases dimensions were made subordinate to perspicuity. On the other hand, no pains have been spared to illustrate the chapter on the mule thoroughly. Diagrams of the same section of a machine are shown with various parts in different positions, in the hope that students may be able to grasp the meaning of the text in regard to this very complicated subject.

HOWARD PRIESTMAN.

May, 1908.



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PRINCIPLES OF WOOLLEN SPINNING

CHAPTER I

THE HISTORY OF THE WOOLLEN TRADE

THE origin of woollen and worsted spinning and weaving is now believed to be of very great antiquity. Wall paintings which depict elaborate dresses, and remnants of fabrics have been found in Egypt, in Babylonia and Assyria, dating from very early times indeed. They are thought to belong to an era of 2000 years B.C., for Herodotus tells us distinctly that the Babylonians wore a gown of linen reaching to the feet, and over this an upper garment made of wool, with a white tunic of the same material above them both. To what extent he alludes it is difficult to say, but the Chaldeans were so far advanced in civilization that they left a record of astronomical observations from 2234 B.C. onwards, and it is therefore highly probable that they were expert in the simpler arts of dyeing and weaving. In confirmation of this, Layard in his book on "Nineveh" tells us that "The dresses were richly embroidered and dyed. The designs upon them were most elaborate, consisting of figures of men and animals, flowers and various other devices."

Many authors incline to the idea that the spinning of long wool or worsted is more ancient than the manufacture of woollen or felted cloth. This is likely to be the case for several reasons. It is often supposed that the Egyptians were the inventors of spinning, and that they applied the process first to flax. This may or may not be the absolute truth, but it does seem quite clear that if Egypt were not the birthplace of many of the arts attributed to it, it was the nursery where many of the most useful processes were brought to maturity and preserved. Clearly, any appliance that is suitable for spinning flax can be made to serve, with little alteration, for the production of long wool yarn; and as almost all known breeds of sheep originally bore long wool, it is not unreasonable to suppose that the longer fibres of animal wool were used before the shorter.

The oldest authentic references available to us in regard to spinning and weaving are those in the book of Job and in the book of Exodus, which date from about 1600 years B.C. Those writers who contend that the spinning of long wool was antecedent to the art of making short wool carded yarn, point also to the fact that all wild sheep are long-woolled or long-haired animals; all of them having a shorter wool or fur growing amongst the roots of the longer fibres. This is still the case in the Vicuna and the Cashmir goat, and it is well known that the fine wools from these animals are the softest and most beautiful wools known to commerce.

All sheep whose wool is useful for the textile arts are supposed to be the results of artificial breeding. Whenever flocks are mentioned in ancient history, it is in relation to centres of civilization. In the Bible we have a curious confirmation of the fact that the art of breeding to obtain

variations in the fleece was known at a very early date. This occurs in Jacob's dealings with his father-in-law. The passage not only tells us that he altered the colour of the wool of the flock to suit his own ends, but that he refused to impart his knowledge to the man to whom the flock originally belonged. There is another reference in the book of Ezekiel to the "white wool" which was brought from Damascus and sold in Tyre, previous to being dyed by the Phœnicians, who were the most celebrated dyers of antiquity. Tyrian purple was widely celebrated, and as any coloured fibres in the wool would greatly detract from the brilliance of the resulting fabric, we may be sure that pure white wool was not only a commodity of great value, but that clever flock-masters were even then well aware how to keep their wool free from the black fibres that occur in the wool of most wild sheep.

It is only when we come down to the Greek and Roman times that we find the first reference to two entirely different makes of cloth with two corresponding types of wool, produced on very different kinds of sheep. With the *Trita* or threadbare cloth we have no concern here. It partook very much of the nature of worsted; but the *Densa* cloth used for the *Toga pinguis* was a napped and felted fabric—a proper woollen cloth. It was made from the wool of sheep carefully cultivated for their very fine close wool, and though it was not much in demand in the warm and sunny climates of Athens and of Rome, such a material would be an absolute necessity to the armies of both Empires, in their long campaigns in cold and mountainous lands. We find also that in the Augustan age it was fashionable to wear cloths with a raised nap or pile. They were known as *Pexae*, and the term leads us to suppose that the nap was raised with a very fine toothed comb.

In the writings of Pliny there is a detailed description of the two kinds of sheep already referred to. The long-woolled sheep was called *Hirtum* or *Hirsutum*. Sometimes, from its hardy nature it was known as *Colonicum* or *Rustic*. The fine-woolled sheep were known as *Molle* (soft), and often referred to as *Generosum* (noble) from the excellence of their wool. It is recorded that their fleeces were often covered with skins to preserve the fibre from undue heat or wind, and from this they derived a third name—"pellitum."

In Pliny's time flocks of sheep existed in Dacia (which is north of the Danube), in Southern Greece, and in Southern Italy, whence they derived their name of Tarentine. They were also known as *Atticum*, and it is this name which is supposed to indicate their real place of origin, for we find from other sources that a very celebrated race of sheep were in existence at Laodicea in Syria. The Romans not only paid attention to their Tarentine sheep, but we learn from both Strabo and Pliny that they introduced their flocks into their Western colonies, and taught the natives of these conquered lands the art of manufacturing fine cloth. The importation was evidently a very great success, for Strabo goes on to say that the Spaniards "formerly imported many garments, but now their wool is better than that of the Coraxi (Caucasus) and so beautiful that a ram of Caucasus was sold for £216 (our value), and that fabrics of extraordinary thinness were made from this wool."

A writer on this subject in Ree's "Cyclopedia," in 1819, says that "there seems no reason to doubt that the Romans were well acquainted with the shawl cloths of Cashmir, and that they would wish to imitate fabrics of such a brilliant and beautiful texture. They were made from very short wool; not

from combed wool as has been generally supposed in this country. The history of the manufacture in Hindustan is proof of a very high degree of perfection to which the fabrication of woollen cloth has been carried in former times; for shawl cloth is only woollen cloth, woven without a twill and unmilled; but it is spun to so great a degree of fineness, from wool so peculiarly soft, that it has never been rivalled by European nations."

When the Empire of Rome declined, and her colonies were a prey to savage invaders, we know too well how many of her institutions, her arts and her manufactures, were wantonly destroyed. But Rome had spread the knowledge of textile arts throughout the then well-known world; and, as a consequence, the art of making cloth was never wholly lost. If we owed nothing more than this to Rome, it would be saying much, but, fortunately, before there came a slackening of the reins of government, Tarentine sheep had got so great a hold in Spanish pastures, that even had the knowledge of wool culture been completely lost, a favourable climate and a splendid breed would long have kept the Spanish flock from deterioration.

Unfortunately, this is not the place to go into this interesting story at greater length, for we have now enough information to convince us that the world-famed Spanish Merino, and the scarcely less renowned breed in Silesia, were both descended from the Tarentine flocks of the Romans. What the woollen trade would have been without these flocks it is quite impossible to estimate, and as there is very little doubt that the Romans first introduced a knowledge of the textile arts into our country, it is not easy for us to estimate how much of our commercial supremacy we owe to them.

The competition of Merino wool with the native wool of

this country deserves a little more detailed attention. Ever since the Roman epoch, Merino has been intimately connected with the woollen industry, on account of its splendid felting qualities. Countries that did not possess Merino sheep, and could not get possession of the wool, never succeeded in making the better class of goods, although they might be very successful in the manufacture of worsted. This fact is very likely to account for the various opinions of ancient writers regarding the exports and imports of wool into England, five hundred years or more ago.

For example, in another article on woollens in Ree's "Cyclopedia," the writer alludes to the superiority of Spanish wool, and to the inability of English wool to compete with it in the production of desirable materials. Mr. James, on the other hand, tries to prove that all Europe was envious of the wool which was grown in this country, right through the Middle Ages, and that none of our competitors had any chance of success unless they were fortunate enough to procure wool which had come from English sheep. It may be that there was some truth in both contentions, but there can be little doubt that the Spanish wool remained much finer and shorter all through the centuries that intervened between the Roman times and the present day.

In support of this theory there are two historical facts that are worthy of mention. Whilst our Islands, and almost all the rest of Europe, were in the grip of the semi-barbarous Northmen, many parts of Spain had found very different masters. We know to our cost that almost all the conquering tribes who came to Western Europe before 1066, made it their business to destroy the arts and cultivation which were so typical of Roman occupation. There is, therefore, no doubt that the manufacture

of fabrics in this country received a very severe set-back for many centuries before the Norman Conquest. Sheep were so scarce in England that a fleece was estimated at two-thirds the value of the ewe which produced it, together with her lamb.

In Spain it was far otherwise. When the Saracens first crossed to Europe, Ree says, quoting from the Archbishop of Toledo, who wrote in 1243, "Spain was fruitful in corn, pleasant in fruits, delicious in fishes, savoury in milk, clamorous in hunting, gluttonous in flocks and herds." So far from destroying the culture which they found, the invaders of that country either carried their own arts of luxury with them into Spain, or, what is more probable, improved such manufactures as they found, by their own superior industry. The revenue of one of their sovereigns in the tenth century amounted to six millions sterling. "A sum," says Gibbon, "which at that time probably surpassed the united revenues of all Christian monarchs. Several centuries later, when the Saracens were expelled, Spain saw no advantage, except a change in religion, to compensate her for the loss of great industry and wealth. On recovery of Seville from the Moors in 1248, not less than sixteen thousand looms are said to have been found in the city, and of these the greater number were employed in the fabrication of woollen cloth."

This quotation is enough to show how likely it is that we are indebted to the Saracens and the Moors for some improvements in the textile arts. At all events, it may be said, without fear of contradiction, that we are indebted to them for the preservation of the Merino breed, and that branch of weaving which was introduced to Spain by the Romans.

Our knowledge of the manufactures in our own country in the earliest times is practically nil, for the most cultured Latin

writers had such a complete contempt for the arts of peace, that it is very seldom they make any reference to details. We know, however, that the Romans had a woollen factory at Winchester, where they produced cloth for their army of occupation in this country. After the decay of Roman power records are so scanty that we know little or nothing regarding spinning and weaving, until after the coming of William the Conqueror. From that time forward there is ample proof that Flanders (Belgium) had already become the leading centre of the woollen trade. Belgians at that day were so proficient in the art of making cloth, that they were considered to be the best craftsmen in Europe, and one quaint old writer, who was anxious to account for their proficiency, states that they were "especially endowed by nature with gifts that qualified them to excell." As a matter of fact, it is difficult to account for the pre-eminence which Flanders had acquired. Their home-grown wool was never of superior quality, but, nevertheless, it is a well-established fact that they were the best makers of cloth in Europe at the time of the Norman Conquest.

Two historians record the fact "that a number of Flemings were driven out of their own country by an extraordinary encroachment of the sea in the time of William the First, by whom they were well received in this country, and first placed in the neighbourhood of Carlisle; but as they did not agree with the inhabitants of the North, they were transplanted by Henry I. to Pembrokeshire. They are said to have been skilful in woollen manufacture, and to have been the first to introduce it into England as a separate trade," distinct from a home industry which produced cloth for domestic use. This supposition is probably correct, for no one imagines that the Roman factory at Winchester continued to exist after the

withdrawal of the Roman legions, and it may be taken for granted that for many centuries, every family spun its own wool, and wove its own cloth, for the clothing of its various members.

Historians of the worsted trade have laid so much stress on the pre-eminence of Norwich in the Middle Ages, that we are apt to overlook the very wide distribution of the woollen industry in even earlier times. At the end of the reign of Henry II. (1189) there were guilds of weavers in London, Oxford, Lincoln, Huntingdon, York, and Winchester, who had paid, or were paying, "fines" to the king for the privilege of carrying on their trade. This shows that trade in cloth was well established, and it is also confirmed by the fact that cloth merchants were paying taxes in various parts of Yorkshire, Norfolk, Huntingdon, Gloucester, Northampton, and Nottingham, as well as at Newcastle-on-Tyne. Their taxes or "fines" were paid to the King "in order that they might freely buy and sell dyed cloths." In the same reign a licence was granted to a guild in London, directing that "if any weaver mixed Spanish wool with English in making cloth, the chief magistrate should seize and burn it." This was doubtless to encourage the growth of English wool, from which our kings derived a revenue. The circumstance rather proves the superiority of Spanish wool, and the jealousy which its importation excited amongst English wool growers.

It is also of interest to notice that in the reign of Henry III. (1216 to 1272) an Act was passed limiting the width of broad cloth and "russets" to two yards, for it completely upsets the theory that is often quoted, "that the first broad cloth was made in England by Jack of Newbury in 1327."

It would of course be quite easy to fill a volume with the

history of the woollen trade and its development, and it is therefore impossible to give a connected outline of its entire growth here, but it is fairly obvious that the trade in England received periodic impulses from the judicious importation of foreign workmen. In the time of Edward III. (1327), as in the time of the Conqueror, the Low Countries were celebrated for their proficiency in the arts of working wool, which was then such an extensive trade, that the city of Louvain was credited with no less than 15,000 journeymen weavers. It is also said that the King's marriage with the daughter of the King of Hainault enabled him to send emissaries without suspicion to invite their manufacturers to this kingdom. How widely these invitations were accepted is clearly proved by the fact that very shortly afterwards foreign manufacturers of—

Fustians	were found in Norwich.	
Baize	„	„ Sudbury in Suffolk.
Says and Serges	„	„ Colchester and Taunton.
Broadcloth	„	„ Kent.
Kersies	„	„ Devonshire.
Cloth	„	„ Kendal, Worcester and Gloucester, Hampshire, Berkshire, and Sussex.
Coarse Cloth or		
Halifax Cloth	„	„ Yorkshire.

In the year 1366 two weavers from Brabant settled in York; “as it may prove,” said the King, “of great benefit to us and our subjects.” Their names were Willielmus and Hanckienus, and it is surmised that the latter, who was known as Hancks, gave his name to that length of skein which is now adopted as the unit of length in various localities.

The Manor of Bradford was in the hands of the De Lacys in 1311, and it is clear that woollen cloths were manufactured there, because even at that date, the straggling village had a fulling mill of its own. Before the close of the sixteenth century it had become a populous and thriving town, largely engaged in the manufacture of cloth. Wakefield, Huddersfield, and Leeds were then only just beginning to compete in the trade for which their districts are now famous, but it is worthy of more than passing notice that towns in almost every county of England were also busily engaged in various textile trades at that date. Hull is also mentioned as a seat of the new industry before either Leeds or Bradford. Throughout the history of the Middle Ages we find frequent records, not only of keen competition, but also of considerable commercial intercourse between this country and the Netherlands. In fact, it is pretty clear that their artisans excelled our own in many branches of the textile arts. For example, there is an entry dated 1549 which reads, "King Edward encouraged foreign Protestants to settle in England, who much advanced manufactures and trade." Until this time it seems quite clear that almost all the foreign emigrants who came to us were chosen men who came by invitation of the ruling kings, but before the close of the seventeenth century we were indebted to the bigotry and to the persecutions of Continental powers for an influx of stalwart Protestant artisans, in numbers far greater than had ever responded to the overtures of enlightened monarchs. In 1567 the barbarous persecution of Protestants by the Duke of Alva in the Low Countries, drove multitudes of their manufacturers to England; where Elizabeth, ever quick to see an advantage, gave them liberty to settle at Norwich, Colchester, Sandwich, Maidstone, and Southampton. These

refugees extended the manufacture of light woollen cloths called Bays and Says, and it is thought probable that they also introduced and taught to the people the art of weaving on a stocking frame.

The last great addition to our manufacturing population from abroad took place when the Edict of Nantes was revoked in 1685. After its repeal Protestants were once more persecuted with the utmost bigotry, for the exercise of their religion, and of the 800,000 who are said to have quitted France 70,000 of the most enterprising and industrious merchants and manufacturers settled in this country. England was again reaping the benefit of the religious troubles of other nations. For these thrifty emigrants were skilled not only in making the coarser stuffs and draperies such as were then being made in Lancashire, Cheshire, and Cornwall, but especially in the design and execution of very fine worsted crepes. These they produced in such quantities that a large trade which had previously gone to France (to the extent of £150,000 per annum) was now entirely supplied at home.

Few subjects could be of greater interest to the economist than a study of the fluctuations in the textile trades of this country from the very earliest times. During the whole of the nine centuries of which we have authentic records, we find that spinners and weavers laboured under foolish and vexatious restrictions, and that wool growers were hampered by State interference. The importation of Irish wool into England was prohibited, and many absurd restrictions were placed on export.

Those who are interested in this subject cannot do better than refer to a book which was written in 1869 on wool and woollens by a Mr. Samuels. It is a lucid work, not too much

encumbered with figures; but one in which many quaint statements may be found. For example, he tells his readers in one place how the King and Parliament sought to improve the state of the wool trade in 1679 by "prohibiting the use of any materials for shrouds of corpses, save those wrought of sheep's wool," and, when speaking of the smuggling which was rife at the same date, he says: "Canterbury and Dover were villainous dens infested with atrocious smugglers. The shoals and channels that embarrassed the mouth of the Stour were peculiarly favourable for a contraband trade. All these facilities were enhanced by the fogs and storms of the whole coast, which created dangers that could only be lightly regarded by bold and skilful smuggling seamen, prompted by the incentive of large and rapid gains. These gains were twofold. The French and Dutch were paying high for wool. The smugglers smuggled, smiled, drank and sold brandy freely. The French bought wool and wondered. Public morality and the revenue suffered, Parliament and the Council issued more decrees, and so the world wagged on."

To show that annoying restrictions were still in existence at a much later date, we cannot do better than refer to a quotation with reference to Halifax during the reign of Queen Mary. It is in the form of a petition which was made against one of the Acts of Henry VIII., and, recording the recent rise of that enterprising town, it reads: "Whereas the town of Halifax, being planted in the great waste of moors, where the fertility of the ground is not apt to bring forth any corn nor good grass, but in rare places by the exceeding and great industry of the inhabitants; and the same inhabitants altogether do live by cloth making and the greater part of them neither getteth corn nor is able to keep a horse to carry wools

nor yet to buy much wool at once, but hath very often to repair to the town of Halifax and there to buy some two or three stone according to their ability; and to carry the same to their houses three, four, or five miles off, upon their backs and so convert the same either into yarn or cloth. By means of which industry the barren grounds in those parts be now much inhabited and above five hundred households there newly increased, within these forty years past, which are now like to be undone and driven to beggary by reason of the Statute."

In 1670 the French were making worsted cloth for which they badly wanted good long English wool, but as the English Government refused to let them buy it in the open market, the wool was bought in secret and smuggled across the Channel, as has already been described.

This brief epitome of history must make it amply clear that, quite apart from ordinary commercial relations, English manufacturers had the benefit of seeing the best Continental practice on four distinct occasions; but it is also important to remember that the machinery on which cloths were produced was extremely elementary until a very late date. It was not until fifty years after the revocation of the Edict of Nantes that the fly shuttle was first invented. In these days we are so used to labour-saving mechanical devices that we hardly realize how primitive was the machinery on which the finest goods were made two hundred years ago. A loom had neither prickers nor a shuttle box, and every weaver had to throw his shuttle with one hand through the open shed of warp and to catch it with the other hand as it emerged from the threads on the farther side. The healds meanwhile were operated by the weaver's feet. To this there was no exception. In weaving 72-inch broadcloth, it was impossible for the same

man to throw and to catch the shuttle. Two men were therefore employed on every loom—one at each end. One of them threw, the other caught, the shuttle. All yarn was spun on spindles, or on spinning wheels; much of it on the former, although the one-thread wheel and Saxon wheel had both been invented at some previous, but unknown, date.

It is only 170 years since all the textile manufactures of this country were carried on entirely by hand. Nothing better was known than hand-carding, hand-combing, hand-spinning, and hand-weaving; and it is very difficult to account for the epidemic of invention which suddenly set in about that time. In 1738 the era of invention was ushered in. Spinning by rollers was introduced by John Wyatt of Birmingham, and patented in the name of Lewis Paul, a foreigner with whom the unfortunate Wyatt went into partnership. In the same year John Kay invented the fly shuttle, whilst he was living at Colchester. Under the old regime, it was necessary for the weaver to keep his hands extended to both sides of the warp, in order to throw and catch the shuttle. This needed extremely dexterous manipulation, and to simplify the process Kay simply lengthened the “lathe” (in which the shuttle runs) by about one foot at either end, and flicked the shuttle to and fro by what was called the picking peg, which was attached by strings to pickers at either end of the lathe. Things now improved by very rapid strides in various parts of the country. Before a year was gone, we find that James Hargreaves of Blackburn (who some years later invented the spinning-jenny) had made the first improvement on the old-fashioned hand cards.

The invention of Wyatt was one that was destined to have almost untold influence in the worsted and cotton spinning trades, although it had never had any extensive vogue in the

making of woollen cloths. The two other inventions have been applied alike to worsted, to cotton, and to woollen. Previous to 1838, all materials were carded on what Mr. Leigh describes as "two wire brushes with the wire bent at an angle." They were about 4 inches wide and 12 inches long; one of them being nailed to a bench, the other having a handle to be held by the operator, who passed it to and fro over the fixed card upon which the cotton to be operated on was placed. After sufficient carding or combing, the material was stripped from the cards by a rod set with spikes or needles, termed a needle-stick, after which it was spun on a one-thread wheel or distaff.

The first improvement on this elementary process of "tumbling" or scribbling, as it was then called, was made, as already stated, by Hargreaves. His invention consisted in the suspension of the upper card, by cords which passed over pulleys having weights attached to their other ends. This device relieved the operator so much, that the cards could be made

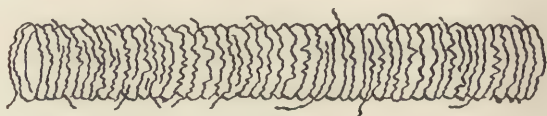


FIG. 1.

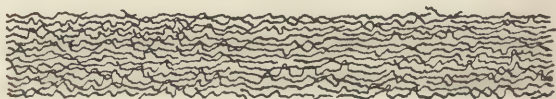


FIG. 2.

larger. The work done on them was also better. The sliver, which corresponded with the length of the card, was also of necessity longer; but it continued to retain the bulk which was characteristic of the first hand cards, because the fibres were still arranged approximately at right angles to the length

of the card. After rolling, the fibres in such a sliver would necessarily be arranged in circular or spiral form (see Fig. 1), not lying lengthwise along the sliver, as is the case in the combed or carded slivers of the present day (see Fig. 2).

After these three improvements had been taken out, there was an interval of just ten years before carding with rollers was first introduced. Almost all writers on this subject including authors who are as reliable as Mr. Baines, have given to Lewis Paul the credit of inventing the art of carding on rollers. It was left for Mr. Evan Leigh to show that this is wholly incorrect; for Paul's specification is entered seven months later than one by Daniel Bourn of Leominster, who applied the rotary principle to carding in 1748. He gives the original specification, and a rude drawing, of which the essential features are here reproduced. Both deserve much more attention than they have yet received; and they are here inserted, although several of the letters are illegible and have been omitted.

"A.D. 1748. No. 628.

"MACHINE FOR CARDING WOOL AND COTTON.

"The properties by which this machine of carding differ from any other method hitherto invented are principally these.

"That the cards are put upon cylinders or rollers, and that these act against each other by a circular motion, and that they may be moved either by hand, or by a water wheel. It may be observed that more or fewer may be put in a machine than four cylinders, though that number is found to be most proper. The cards are wrapped round the cylinders, which by their circular motion, and acting upon one another, card the wool or cotton sufficiently for fine spinning.

- (a) Place where a girl sits to take off wool or cotton when carded on cylinder No. 1.
- (b) A large wooden frame on which all the work is fixed.
- (c) Iron frame screwed to the wood end.
- (d) Side irons which keep the cylinders at proper distances from each other.

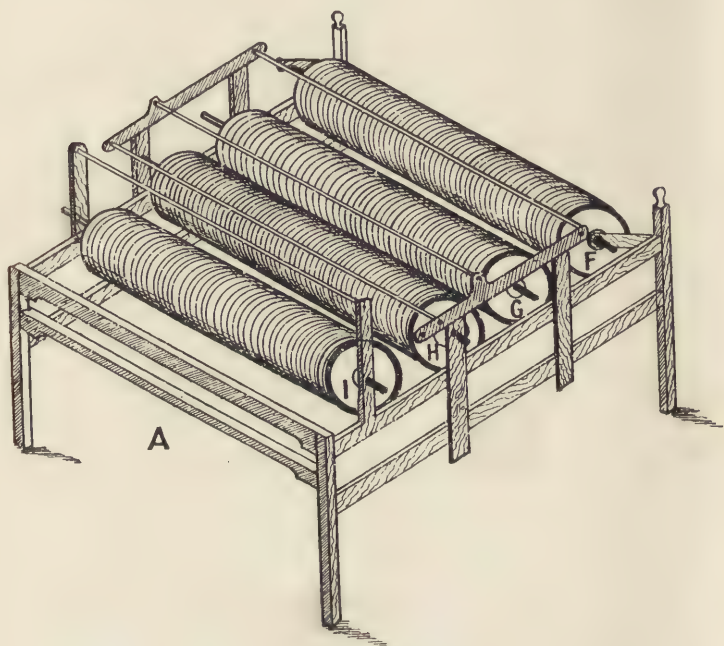


FIG. 3.

- (e) Iron bars that are screwed to the side irons.
- (f) First cylinder or roller.
- (g) Second cylinder or roller.
- (h) Third cylinder or roller.
- (i) Fourth cylinder or roller.
- (k) Distinct frames belonging to each cylinder.
- (l) Sliding plates to which each cylinder is fixed; and by

means of which they may be set at any distance from each other.

"N.B.—A frame with three cylinders is the same as this model when the fourth cylinder is taken away.

(Signed) DANIEL BOURN."

It is difficult to understand why this machine has escaped the notice that it deserves, for it was infinitely superior to that for which Paul obtained so much renown. It contained almost all the motions that are necessary for continuous production; in fact, it only lacked a feed sheet and doffing comb to make it into a perfectly practical carding engine. Paul's first patent, on the other hand, was little more than a pair of somewhat glorified hand cards. Its only interest to us at the present day lies in an arrangement which he devised for turning out a continuous length of sliver. It was in reality a piecing machine; that is, an arrangement which was once in universal use, and is still to be seen in some old-world factories, for piecing together the various sections of sliver which fall from a doffer that is covered with sheets of clothing. (See chapter on Carding.)

Of this invention Paul himself says—

"The cylinders being in their places as described in the figure, the wool is to be took off the rows of cards and laid down on the ribband by means of a stick with needles in it parallel to one another, like the teeth of a comb. The wool being on the ribband, the wheel and consequently the cylinder (*g*) are turned about by the foot and the wool and the ribband are wound upon the cylinder, so far that you have enough of the row out to connect with the next row of wool that is took off with it . . . and so on until you have made an entire roll

or filament of all the rows you have taken off the carding and then it will be fit for use."

In one respect only this invention is of immense interest. Paul was the first man who obtained a continuous carded sliver from which yarn could be spun; but so far as we know, his second patent, filed at the same time, was the one which brought him fame. In the cotton trade at least, he deserves

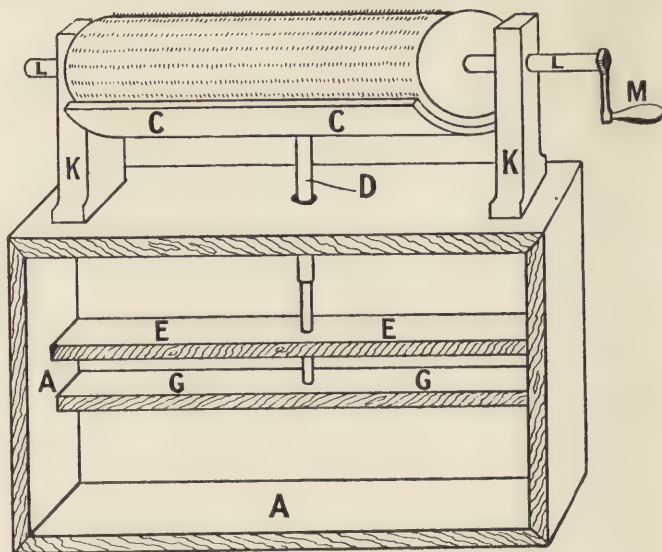


FIG. 4.

great credit; for though he certainly was not the inventor of carding by rollers, it is perfectly clear that he was the first who used a carding cylinder in conjunction with what we now call "flats."

He describes the machine as follows:—

"Fig. 2 represents a card, wrapped on a cylinder or roller, which is to revolve on its axis L vertically, and able to be

moved from left to right and from right to left horizontally. This card consists of parallel rows of cards with intervening spaces, as before described, instead of the upper card used to the engine in Fig. 1. There is a concave CC lying below the cylinder in which a card is fastened, this concave has an arbor D that going through the top of the frame and also through the crossbar E, rests on a lever GG. By the vertical rotary motion given to the windlass, the wool is carded and equally distributed on the card by sliding in its horizontal direction; the concave being properly applied to it. After the wool is properly carded, it must be took off the rows by the needle-stick, and wound upon cylinders as directed in the description of Fig. 1 of the engine."

Unfortunately, neither Bourn nor Paul made any commercial success of their inventions, for Paul and Wyatt's factory at Northampton was broken up, and the carding engine was sold to a Mr. Morris, who took it first to Leominster and finally to Wigan. About the year 1760 the first Robert Peel saw the machine in that town, and with his keen business insight he at once recognized the great possibilities that it contained, but even with the help of the inventive Hargreaves he failed to make a commercial success of it, and laid it aside for quite a number of years.

The first practical addition to the roller card of Bourn, was made by John Lees, a Quaker of Manchester, in 1772. He applied a perpetual revolving cloth, or feed apron, which was later improved upon by Arkwright, a man who was blessed with an extraordinary genius for putting the products of other people's brains into practical shape. In 1773 the finishing touch was given by James Hargreaves. This was the invention

of the extremely ingenious contrivance that is known as the doffing knife. Like many other very valuable motions, this was patented by Arkwright in his own name. Hargreaves received neither credit nor cash for his valuable addition to the science of carding, but there is little doubt that it was his finishing touch that made the carding engine a practical tool of immense importance in all the textile trades. Now, for the first time, could slivers of cotton or wool be turned out in unbroken lengths of unlimited extent.

It is a curious fact, as already noticed, that Wyatt and Paul's patent for spinning by rollers, was the first to usher in the age of invention in the textile trade. Though this patent is really one for drafting by rollers, the closing lines of the specification indicate clearly that the patentees had fully grasped the possibility of spindle draft as well. The patent was never of any value to its owners, but in 1758 Paul again applied to the Patent Office for protection for a machine in which he discarded the worsted principle altogether. He gives both drawing and description in his specification, which prove conclusively that drafting was to be done solely between one pair of rollers and a spindle which had a positive take up. The motion of both rollers and spindles was continuous, on exactly similar principles to those of the cone roving box. The action of the machine was much more nearly allied to that of a spinning frame than to the intermittent action of a mule. He says of it in A.D. 1758—

“The several rows or filaments so taken off must be connected into one entire roll which being put between a pair of rollers or cylinders, is by their turning round, delivered to the nose of a spindle, in such proportion to the thread made as is proper

for the particular occasions. From thence it is delivered to a bobbin or spole or quill, which turns upon the spindle and which gathers up the thread or yarn as it is spun. The spindle is so contrived as to draw faster than the rollers or cylinders give, in proportion to the length of the thread or yarn into which the material to be spun is proposed to be drawn.

(Signed) LEWIS PAUL."

Although this second patent involved the principles of spindle draft, its mechanism and arrangements were not of a nature to suit the woollen trade, and they have never been extensively applied. It was in 1764 that James Hargreaves, who was a weaver at Standhill, turned his attention to the production of machine-made woollen yarn. In 1767 his machine was complete. It was on an entirely different principle from anything previously constructed, or thought of, and it was the model from which all woollen mules have developed; for we find embodied in it—

(1) A method for the delivery of a certain length of carding or slubbing which was extended and twisted, before any further length was paid out.

(2) A system of spinning with a long stretch of slubbing or yarn, between the mechanism which held the slubbing C and the spindles B.

(3) In this stretch the yarn was extended and twisted.

(4) It also contained an arrangement to run the spindles at two different speeds, one rapid, to put twist into the yarn, and a second slow, to wind the yarn on to the spindles.

(5) A guide or pressure wire, to guide the yarn during winding on to the spindles.

Hargreaves is supposed to have invented his jenny for the exclusive use of his family; for he kept its existence an entire secret until the quantity and excellence of the yarn which came from his house aroused suspicions. When once the secret was out the inventor's position was one of great peril; for the hatred of machinery by the working classes was so bitter that they were not content with destroying his machine, but threatened to take his life if he had the temerity to remain in the district. It is fair to the workmen of that date to say that complete ignorance of economics was not confined to that

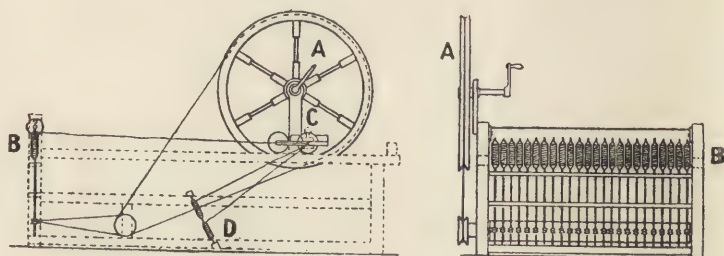


FIG. 5.—HARGREAVES' JENNY.

- A. The handle and wheel which drive the spindles.
- B. The spindles fixed in the frame.
- C. The movable clasp and carriage.
- D. The bobbins from which the "slubbing" is unwound.

class alone. It was quite common for magistrates to side with the mob in cases of machine wrecking. Even as late as 1817 an enlightened writer says of these same inventions—

"Had they not entirely changed the mode of carding and spinning cotton, the woollen manufacture would probably have remained at this day, what it was in the earliest ages of civilized society. That it would have been better for civilized society had it so remained we readily admit; but after the

improved modes of working cotton were discovered this was impossible."

It is said that three expert spinners, using hand wheels, were only able to supply one weaver with the yarn he needed, when his loom was equipped with Kay's fly shuttle and its picking peg; and a quicker method of spinning was so badly needed, that in spite of bigotry and prejudice, in less than twenty years, more than a million and a half of Hargreaves' jenny spindles were at work in England. For some years after the jenny was in regular work, much of the carding, and all the slubbing was prepared for it by hand; the slubbing being done on one-thread spinning wheels. It was not until after the invention of the mule that the "billey" was introduced to produce the slubbing more rapidly than was possible on hand wheels.

To understand the sequence of events about this time, it is necessary to take notice of at least one machine that has little or no connection with woollen spinning. Arkwright, whose marvellous ability for assimilating other people's ideas has already been mentioned, perfected the construction of Wyatt's roller frame in 1769, and he was so successful in applying it to his own ends that, unlike nearly all his contemporary inventors, he amassed a huge fortune before he died. In 1779 a young man named Crompton first succeeded in spinning yarn upon a mule. He began to work on this machine in 1774, and he chose its name himself because he said it was a cross between the roller frame of Arkwright and Hargreaves' spinning-jenny. Crompton was very poor and, unlike Arkwright, was blessed with very little of the wisdom of this world. He took no patent out, disclosed the principles

of his machine before the world—and made the cotton trade. Many years afterwards, as Professor Barker says, “he proved before the Committee of the House of Commons, that by means of his invention he had contributed more than £300,000 per annum to the revenue, and for these services a grateful country granted him the magnificent sum of £5000, which he subsequently lost, and would have died in poverty had not some charitable cotton spinners contributed to keep him from starvation.”

In combining the principles of the mule and the roller frame, Crompton made the rollers of his machine a fixture,

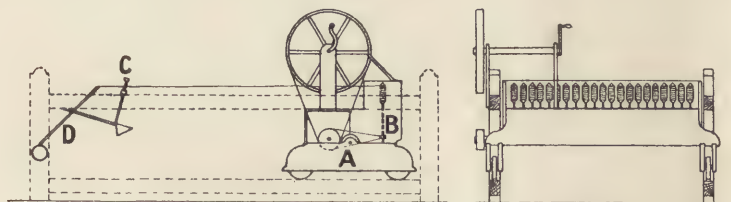


FIG. 6.—A BILLEY.

- A. Movable carriage carrying the spindles B, and the wheel and handle to drive them.
- C. The fixed clasp.
- D. The inclined board on which the cardings are laid.

and for the first time placed spindles in a movable carriage. For this he must for ever claim an important place amongst the inventors in the woollen trade.

The jenny long continued to be used; in fact, it is still in use in isolated factories where hand-made tweeds and friezes are made from hand-spun yarn in remote corners of our islands. The moving carriage mule replaced the jenny slowly, but, curiously enough, the “slubbing billey” continued to be constructed with spindles in a carriage, but with a clasp instead of with the rollers that Crompton used.

Although the spinning-jenny was invented by Hargreaves exclusively for the making of cotton yarn, it was very quickly applied to the spinning of wool; but it is difficult to say when the first machine was put up in Yorkshire. Mr. Jubb, who wrote in 1860, says that "seventy years ago (*i.e.* in 1790) scribblers, carders, and billeys were at work in Hanging Heaton, near Batley, the cards being driven by horse gins." If this was really the case, it is clear that the woollen trade was very prompt in adopting the billey, for it was designed on the lines of the mule, after the nature of Crompton's machine had become public. The date of the first billey may therefore be estimated as 1780 or 1785, and its utility for the woollen trade must have been very quickly realized wherever machine cards and jennies were in use. In cotton districts, on the other hand, its life must have been very short, for it could not possibly compete with Arkwright's roller frames for reducing cotton for the mule.

In 1817 the billey was in general use in Yorkshire. It was used to reduce the thick $2\frac{1}{2}$ -skein slubbing that came from the old-fashioned carding machines, to a size from which it was suitable to spin 25-skein yarn. The cardings were then produced in short lengths, and it was the business of the billey not only to reduce them in size, but to piece them all together giving them a slight twist to increase their strength, and winding them on to a bobbin in the form of a thick, loose yarn. In this condition it was known as "roving." It was small enough in size to be spun on the jenny to any size of yarn that was required. It is said by those who ought to know, that the prosperity of the old woollen trade was at its height in the days of the billey and the jenny; in days before the ring doffer was introduced, when the length of the carded

sliver corresponded with the breadth of the card, with the fibres that composed the carding lying across and not along it. Let us take an illustration from the figures that have been already given. When we speak of $2\frac{1}{2}$ -skein carding, or condensed sliver, coming from a machine 1 yard in width, we mean that when $2\frac{1}{2} \times 256$ lengths have been put up end to end in the slubbing billey, their weight will be exactly 1 lb. It was customary for the billey to extend or draft these 640 yards to five times their original length. If the draw of the billey from the tip of the spindle to the clasp or slide be taken as 50 inches, it means that 10 inches only of sliver would be paid out, and that those 10 inches would be extended to 50 inches by the retreat of the spindles in the carriage. If the spindles were suitably rotated, this would give a $12\frac{1}{2}$ -skein slubbing, containing only just enough twist to make it strong enough to wind. This $12\frac{1}{2}$ -skein yarn was then taken to the jenny to be spun. In a jenny with a draw of 50 inches, 25 inches would be allowed to pass the clasp before any drafting took place. Because the spindles of the billey and the jenny ran in opposite directions, the first effect of the spinning process would be to remove this twist. When all the turns were taken out, twist in the spinning direction would be put into the slubbing. As soon as the slubbing again contained sufficient twist to make drafting regular and easy, the clasp was drawn steadily away from the spindles by the operator's left hand, at the same time that he inserted more twist by turning the driving wheel and the spindles with his right hand. Those who are acquainted with hand-spinning are well aware that the more the thread is extended, that is to say, the finer the yarn becomes, the more twist will it require to keep it of equivalent strength. It was of course the business

of the spinner to see that he was inserting just so much twist that the drafting would continue with equal ease all through the retreat of the clasp and the carriage. When he had spun his 50 inches of yarn, his next act was to reverse his spindles and lower his guide wire. Then, whilst he pushed the carriage in with his left hand, he rotated the spindles at such a pace that the threads he had spun were wound compactly in cop form on to the spindles. The yarn was then ready for weaving, 1 lb. of it contained exactly ten times the length of 1 lb. of carded sliver; in other words, the carded sliver had been drafted to ten times its original length in the two spinning processes. It would measure 6400 yards to the pound, which is the equivalent of 25-skein yarn.

At the date of which we are speaking, the advantages of drafting by rollers had been so far recognized in worsted spinning, that six distinct processes had been introduced between the hand comb and the spinning frame. The first was known as a planker, the second, third, fourth, and fifth were called drawing-boxes, and the last was known as a rover. They had an average draft of 4, and as $4^6 = 4096$, that amount of draft, together with an equivalent number of doublings, was given to all the material that went through those processes. At the present time there are often twelve processes used to obtain the same end in making worsted yarn. These processes involve many million doublings with an equivalent amount of draft, which depends entirely on the length of the wool. Thus we find that whilst the worsted trade has increased the thickness of its tops, and has spared no expense or trouble to perfect the structure of its yarns, the woollen trade has—

First, enormously reduced the size of its carded slivers;

Second, entirely altered the arrangement of the fibres in those slivers;

Third, completely cut out one of its drafting processes; and

Fourth, reduced the draft in the one process that remains, until the total extension in length is often little more than 10 per cent. instead of being 1000 per cent., as it was when West of England broadcloths were the first cloths in the world. Such a state of affairs is difficult to reconcile with all that is said in favour of spindle draft. If spindle draft possesses any real virtue, it must surely be worth while to obtain an extension, by that means, of more than half the original length of the carding. If, on the other hand, it has no special virtue, why not add spindles to a carding frame and twist each condensed sliver as it leaves the tapes? It would save space and power.

It would be a tedious and unnecessary process to follow the infinite number of small improvements that have resulted in the evolution of the present self-actor mule from the jenny as devised by Hargreaves. Although Crompton's mule was not designed for the woollen trade, it is clear that the automatic motions which he and others applied, had a definite bearing on the development of the woollen mule, although that machine has no drafting rollers. Crompton's mule was not what we should call automatic. On the contrary, it is clear that even when Baines wrote in 1835, machines which were really self-acting were far from universal in the trade. He credits Mr. William Strutt, of Derby (a son of Arkwright's partner), with building the first self-actor; but he inclines to the opinion that the imperfect workmanship of that date, 1790, rendered his invention worthless. He also gives at length a letter written

by William Kelly, in 1829, to Mr. Kennedy, in which he states that—

“I first applied water power to common mules in the year 1790. That is, we drove the mules by water, but put them up (that is, the carriage or the spindle frame) in the common way by applying the hand to the fly-wheel; and by placing the wheel or the mules right and left, the spinner was thereby enabled to spin two mules in place of one.”

The letter then alludes to several new motions that he applied, including a coping motion and a counter faller, which have both been claimed as the inventions of others at much later dates. The letter concludes by saying—

“It will naturally be asked, why were not the self-acting mules continued in use? At first, you know, the mules were about 144 spindles in size, and when power was applied the spinner worked two of them, but the size of the mules rapidly increased to 300 spindles and upwards, and two such mules being considered a sufficient task for a man to manage, the idea of saving, by spinning with boys and girls, was thus superseded.

(Signed) W. K.”

This Mr. Kennedy added his quota to the improvement of the mule as we see it to-day. It was he who first contrived to get the increased spindle speed by automatic motions, and he applied it to the machine then known as the hand mule. Even to-day this kind of mule is found in little factories in secluded valleys. The name is a misnomer, for though, of course, some of its movements are directed by hand, it is

driven by power just like its more perfect successor, the self-actor.

The final stages in the development of the mule may be referred to very briefly, but they must not be regarded as less important on that account. We have already seen with what rapidity the mule was adopted in the cotton trade. It is typical of the conservatism of the Yorkshireman that it was not applied to woollens in the headquarters of the industry for nearly fifty years. The billey was in use in Hanging Heaton in 1790; the theory of the moving spindle carriage was therefore known, and yet it took a period of half a century to make the very slight alteration or compromise between the billey and the cotton mule. Jubb tells us that the mule was not adopted in Batley till 1830; and he adds, in 1860, "It is a question whether the villages that cluster round Leeds are supplied with this useful substitute for the jenny." In his day the piecing machine was replacing the labour of children, who used to put up cardings to the slubbing billey. The size of that machine was rapidly increasing. It was called a tommy when it contained 70 or 80 spindles. "The horse," he says, "or modern machine of the same class, has variously from 100 to 150 spindles, and in some cases upwards. These machines are propelled partly by steam power, which was not formerly the case. Consequently, the largest of them are not of likelihood more easily managed by the workman than the first small machines were." With the coming and perfection of the mule, the development of the woollen process may be regarded as complete. It is true that there have been many alterations in the machine since that day. Ring doffers and tape condensers have reduced the size of sliver, and displaced the roving process, but opinions differ as to whether

this is progress. It may be that Vickermann was right when he called it "advancing backwards." Cheapness of production is all very well, but cheapness at the cost of deterioration is a doubtful advantage, and it is still an open question whether the woollen trade is better off, or worse, for the economies that have been practised. If woollen goods are to be thought of in the future as they used to be in the past, as being essentially milled fabrics, the yarns of which they are to be composed must be constructed with this one end in view. Those who spin yarns for fancy woollen tweeds may take a different view, and may hold that view correctly.

CHAPTER II

WOOL, AND WOOL WASHING

THE student may have noticed that hitherto nothing has been said in reference to the chemical construction of wool fibre. It is of course possible to state approximately how much carbon, hydrogen, nitrogen, and sulphur are to be found in any given sample, but as a matter of fact such a statement of figures is of little value to the chemist, and of still less practical interest to the student or the business man. Both Continental and English chemists have been at work for many years on the constitution of wool, but results are always liable to vary slightly—firstly, because of the variation of the wool fibre itself, and secondly, because it is impossible to decide how far the uncombined water contained in the fibre should be removed before the analysis is begun. So far as is at present known, the composition of wool fibre is exceedingly complex, far more so, for example, than is cotton. Cotton consists of little else than cellulose, which is usually written $C_6H_{10}O_5$. This must not be taken to mean that cellulose is a definite substance whose properties do not vary. It should rather be regarded as a generic term which includes a number of substances which have a similar chemical composition. It is a most important substance, as it forms the basis of all vegetable tissues. Wool, on the other hand, is one of the albumenoid or proteid substances which form the chief part of

the solid constituents of the blood, muscles, and other organs of animals. They also appear in plants, principally in the seeds. Their constitution is still so obscure that no formula of their ultimate analysis can yet be calculated. It is not even known with any certainty whether some of them are compounds or only mixtures. Schorlemmer says that they are all very similar in composition, containing per 100 parts—

52-54 Carbon
7- 7·3 Hydrogen
13-16 Nitrogen
21-26 Oxygen
1- 1·6 Sulphur.

The four analyses which are given below show how nearly wool approaches to the figures. Dr. Matthews describes it as a proteid. It is usually termed keratin, and placed in the aromatic series. This implies that it therefore contains the benzin ring, but almost everything concerning it is uncertain, except that it is exceedingly complex.

TABLE I.

PROPORTIONS OF ELEMENTS IN WOOL FIBRE AND IN LEATHER, ETC.

	Scherer.	Mulder.		Bowman.	Von Schroeder ¹ and Paesler.	
	Wool.	Wool.	Horn.	Wool.	Hide.	Gelatin.
Carbon	50·65	50·5	50·54	52·0	50·2	51·0
Hydrogen	7·03	6·8	6·91	6·9	6·4	6·5
Nitrogen	17·71	16·8	16·80	18·1	17·8	18·1
Oxygen	{ 24·61 }	20·5	22·07	20·3	{ 25·4	24·2
Sulphur		5·4	3·60	2·5		

¹ In Schroeder's determinations, traces of sulphur are probably included in the oxygen, which is obtained by difference.

Wool and hair are by no means the only animal substances

that consist largely of keratin, for the epidermis and other parts of most skins are practically identical with wool fibres in their constituent parts, even horn and other gelatinous substances being similar, but differing as much from one another as they differ from the wool, whilst all resemble gelatine very closely. These facts go to show that the mere proportions of the elements in wool are in themselves of little practical value, and the attention of researchers may therefore be turned with greater advantage to the structure and properties of the various substances that are found on wool when in its natural state. These are commonly known as yolk or suint and wool fat. The suint is composed of salts of potassium, part of them combined with animal oil in such a way that the whole is completely soluble in water, although opinions differ as to whether it is or is not a soap in the true meaning of the word. In a good P. P. greasy wool which would yield 50 per cent. in normal condition, when clean, it would be fairly safe to conclude that there would be approximately 15-20 per cent. of dry suint, 10-15 per cent. of sand or earth, and 15-20 per cent. of wool fat.

TABLE II.

CHEVREUL'S ESTIMATE OF IMPURITIES IN WOOL.

Earthy substances	26.06
Suint.	32.74
Fatty matter	8.57
Earthy matter fixed by grease	1.40
Wool, clean	31.23
	<hr/>
	100.00

The suint in its turn might contain 50 per cent. of carbonate of potassium and about $\frac{1}{2}$ per cent. of sulphate and chloride of potassium.

The wool grease proper consists of two fatty acids, one a

solid fat that was named stearine or wool suet by Chevreul, the other being a liquid at normal temperatures, named elairine or wool oil by the same worker.

The former is very difficult to saponify, but the latter emulsifies when boiled with water, and saponifies with caustic potash.

It is of course obvious that the properties and constituents of these wool lubricants should be well understood in order that they may be treated with the most suitable chemicals in the washing. They will then be removed from the fibre with the least possible expense and with the least possible injury to the constitution of the fibre itself. But something more will be said on the practical application of these figures a little later on.

Wool Washing.—There are few things more detrimental to the true interests of the trade than is the very common idea that the *one* object of washing is to get wool “a good colour.” It may, in fact, be laid down as an axiom that washing should only mean the removal of those impurities which prevent the wool giving the very best results in every after process through which it is destined to pass, with special regard to the dyeing and finishing.

Wool contains many constituents which can be affected and partially removed by severe washing, and if these be once extracted by excessive heat or strong reagents the wool not only loses unnecessary weight, but it also loses some of its original properties, which can never be imparted to it again.

The washer must class wool under at least four different heads, viz. greasy, scoured, skin, and slipe—the term **skin** being used to denote wool removed from the skins of slaughtered sheep by means of a sweating or similar process, **slipe** being the

commonest term for wool taken from skins by lime. In the bowls each class should receive a different treatment, but in practice the different sorts are very often blended prior to washing, with the idea that the better classes will help the poorer; and this quite irrespective of the fact that the lime and other matter to be found in slipes may do injury to the greasy, which is out of all proportion to the improvement that the slipe itself may derive from the combination.

To lay down rules on such a matter is impossible. There are many reasons for mixing two kinds of wool in one pile, and it is often done without the slightest detrimental effect in the washing; but the old proverb still holds good that "a silken purse cannot be made out of a sow's ear," and wools which have once been really injured by the method of their removal from the skin can never be made to take a finish equal to the perfect greasy fibre. To be dogmatic on this subject would only be to show ignorance of facts, for a long and varied experience is the only means of obtaining the knowledge requisite to assess the relative advantages and disadvantages of each individual case; but a consideration of the peculiarities of the various classes may be of assistance to the blender as well as to the washer.

Greasy Wool.—In addition to the original supply of greasy wool, almost all the best flocks which used to come to this country as washed fleece now come in the grease, so that the total quantity offered is now very large, being 70 per cent. of the total number of bales sold in London in a year.

It reaches the user just as it is shorn from the living sheep, and the fleeces therefore contain all the natural secretions which are present on the outside of the fibres during life, as well as the whole of the yolk or suint within the individual fibres, and

all the dust, sand, and earth which have adhered to the fleece during life.

The surplus lubricants keep the wool in the best possible condition during transit, and if the dirt and extraneous grease are removed in such a way that none of the internal constituents of the fibre are extracted in the process, the wool will go through every process with a maximum amount of suppleness and nature. To attain this object the temperature of the water and the amounts of soap and alkali must be kept as low as possible during washing. To avoid the use of strong reagents plenty of water is necessary. Bowls 43 feet long, holding as much as 1500 gallons, have been found to answer very well.

No rule or figures can possibly be given for the washing of this or any other class of material, for hardly any two marks require identically the same treatment, and every blend must therefore be given just as much soap as is necessary, and no more carbonate of soda (or carbonate of potash) than will keep the suds nicely alkaline.

Scoured Wool is fleece wool clipped in the colony, but scoured there, prior to packing. It varies very greatly in its yield. The whitest and lightest qualities have already been washed so thoroughly that almost all sand and grease have been removed, and the washing prior to carding serves rather to revivify the wool than to remove impurities. Good soap in water at 115° is all that is necessary for the purpose. Blended with greasy of equivalent quality this sort washes well, and will probably be improved in handle without detracting in any way from the quality of the greasy.

Like all other classes of wool, scoureds vary very greatly in their yield. The heavier of them take a good deal of washing, and some of them require the addition of a considerable amount

of alkali as well as soap to the bowls. For most trades they can be blended with advantage with greasy, but at the same time it is generally admitted that a pure greasy produces the best top for spinning, and one which gives a superior finish in many kinds of cloth.

Skin Wools.—Wool which has been removed from the skin by any other than the lime process is almost always partially cleansed, and as the grease and dirt are removed whilst the wool is still on the skin, no felting or matting of the fibre occurs, and the wool reaches the user in a very free and open condition. Such wools require so little agitation in the washing that they go to the carding-machine in perfect condition, and make a carding very free from knots and short wool. The absence of natural lubricant leaves the fibre dry and wanting in suppleness, and in treating such wools the main object of the washer should be to replace this loss by some other natural or artificial matter of a suitable nature. If these dry skin wools are blended with greasy, prior to washing, the excess of natural fats in the one will often be absorbed to some extent by the other, but fibre once robbed of its yolk can never be made "as good as new."

Slip Wools.—Those who have to treat limed wools know what an enormous amount of soap it takes to "get them through the rollers." The lime will decompose both soda and potash soaps which are used, forming from them harmful compounds, because the lime salts have greater affinity for the acid fats than have the soda or the potash contained in the soap.

As lime is in itself an alkali, the addition of any other alkali is of no use. The lime must be neutralized before soap is applied to the wool, and this can only be done perfectly by the use of acid.

There are wools on the market which contain as much as 8 per cent. of lime, or 19·2 lbs. in every pack, which if present as calcium would destroy 288 lbs. of soap, if it were treated with soap alone. A sticky lime soap would also be formed which would settle on the fibre and make it impossible to cleanse the wool thoroughly. If acid were used it would require about 40 lbs. sulphurous acid to convert the lime into a harmless soluble salt, and say 5 lbs. of carbonate of soda to remove all trace of acid. The wool would be almost clean when it came from the carbonate bath, and it would only require a very small amount of soap to finish the washing and produce the best possible result. If a special set of five bowls were used, the cost of wages would be equal in both cases, but as most combers would have to treat the wool twice in some existing set, we may reckon double wages, and still have a great saving as well as far better work.

In almost all the early washing machines the rakes were used to move the wool forward through the stationary sud, to open it, and to deliver it into the nip of the roller in such a condition that the dirt might be easily squeezed out.

The rollers of the hand bowl usually stood at some height above the sud, and as the wool was lifted to them most of the water ran back into the bowl, leaving the wool in a sodden and relatively compact mass on the feed-apron. In this respect machine bowls have a very great advantage, because in the best types of washing machines the wool is practically floated into the nip of the rollers. To see the advantage of this treatment it is only necessary to try a very simple experiment. If a staple of wool be thoroughly saturated and suspended in water, every fibre will at once separate itself from its neighbour, and if it go to the squeeze in this condition any sand or dirt

can very easily get away. If the staple be lifted from the water without being squeezed in any way, it will be seen to shrink in bulk, so that the fibres all touch one another. In the hand machine the wool reached the rollers in the latter condition, and the dirt was squeezed into the fibre, instead of being squeezed out into the water, as it should be.

TABLE III.
SHOWING RELATIVE AMOUNTS OF SOAP, ALKALI, AND TEMPERATURE
FOR WOOLS WASHED IN TEN HOURS.

	Greasy.	Washed fleece.	Scoured.	Skin.	Slupe.
Yield	50 %	66 %	75 %	80 %	60 %
Packs washed	20	15	13 $\frac{1}{2}$	12 $\frac{1}{2}$	17
Clean wool	10	10	10	10	10
1st bowl.					
{ Heat	120°	120°	120°	120°	125°
{ Alkali	40 lbs.	40 lbs.	46 lbs.	50 lbs.	80 lbs.
{ Soap	120 "	90 "	120 "	100 "	240 "
2nd bowl.					
{ Heat	115°	115°	120°	120°	120°
{ Alkali	—	—	—	20 lbs.	40 lbs.
{ Soap	60 lbs.	70 lbs.	90 lbs.	80 "	180 "
3rd bowl.					
{ Heat	115°	115°	115°	120°	125°
{ Alkali	—	—	—	—	—
{ Soap	50 lbs.	50 lbs.	70 lbs.	80 lbs.	80 lbs.
Total alkali	40 lbs.	40 lbs.	46 lbs.	70 lbs.	120 lbs.
" soap	230 "	210 "	280 "	260 "	500 "
Alkali per pack	2 lbs.	2 $\frac{1}{2}$ lbs.	2 $\frac{1}{2}$ lbs.	5 $\frac{1}{2}$ lbs.	7 lbs.
Soap "	11 $\frac{1}{2}$ "	14 "	21 "	21 "	30 "

A machine made by Messrs. Jefferson Bros. was most perfectly adapted to squeeze the wool whilst it was quite submerged, but all modern machines take the wool to the rollers in a super-saturated condition.

The squeeze-head of the M'Naught machine (Fig. 7) is designed to squeeze the wool in a condition almost equal to total immersion. The wool does not actually float into the nip of the rollers A, but it is washed forward by such a flow of water that the fibres never lie in a sodden mass as on an apron. They are separated from each other by the amount of water they contain, so that it is easy for the sand to escape. Once away from the fibre the sand and dirt can never come again to the rollers, for, instead of falling back into the water which contains the wool, the stream of sud from the trough B, where the wool is washed, washes the sand through the perforated plates into trough C, from which it is pumped to the settling tank D. Here there is no agitation, and the sand quickly settles to the bottom, which is so shaped that everything falls towards the outlets, and when the cocks are opened all sediment is readily flushed clear away.

If any sud in which wool has been washed be allowed to stand, a film of insoluble matter will soon form on the surface; and if there be any salts of lime or magnesia present in the water, the scum will probably assume the character of a sticky and insoluble froth. This is the product already alluded to as lime soap.

The tank used for settling may therefore have another use of equally great if less obvious importance, for whilst its stillness allows the heavy matters to sink, it allows all insoluble oily and soapy matter to rise and float on the surface. If wool is washed in trough C (Fig. 8), above and quite separate from the settling tank D, these lime soaps and other floating impurities will never come into contact with the wool at all if the sud which is to go to the washing trough be pumped from a point in the settling tank well above the bottom

and well below the surface. In a machine of this type made by John Petrie, Jun., the only lime soap which could adhere to any fibres would be the very small quantity existing in a state of subdivision so minute that it could be held in suspension in the water.

In most types of machines the forks are used to move the wool through the sud, but in the type in question the forks or other mechanical contrivance may be rather said to prevent the wool being washed forward too fast by the flow of water which is pumped up and rained, or allowed to flow into the trough at the end where the pump E is shown.

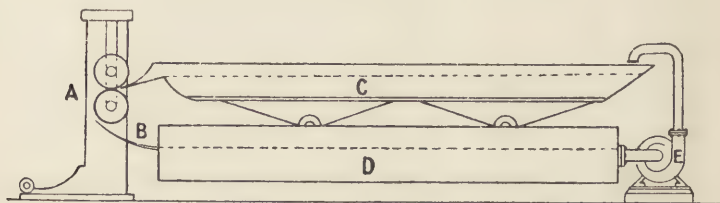
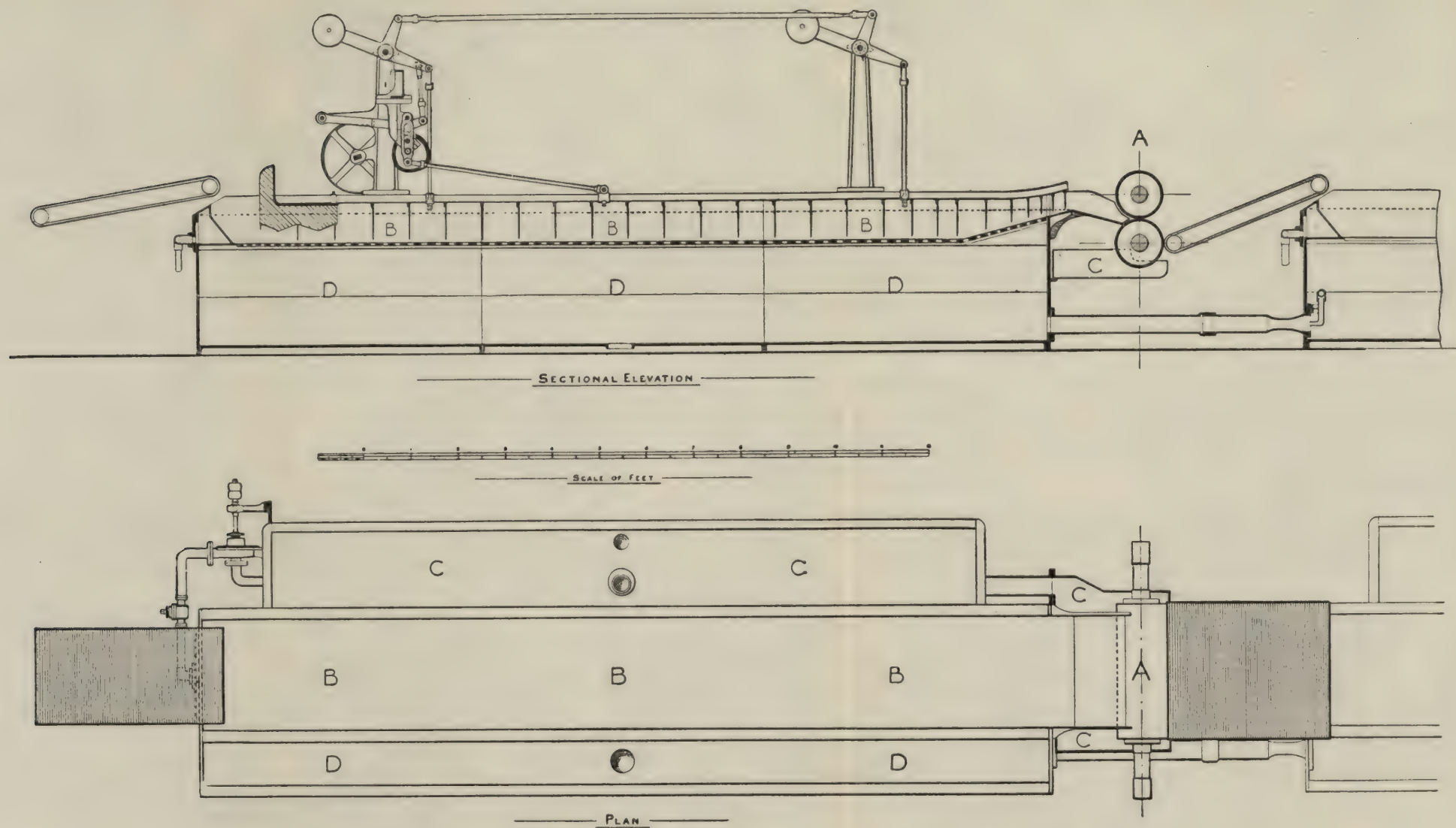


FIG. 8.

Fork Motions.—There are three entirely different types of forks now in general use, the oldest form being that in which each rake is driven in elliptical orbit by a separate crank. A machine of this kind is made by Messrs. Hoyle & Preston. The forks work in a single deep bowl, and as they agitate the sud more than any other type, they are very suitable for slipes and other wools which are difficult to wash.

The type made by Messrs. J. & W. M'Naught (Fig. 7) is simpler in its action, all the forks being fixed to a long frame, so that they move forward together through the sud on the forward stroke, when they rise and travel back above the surface. Sometimes a shaking motion is introduced before the forks rise, to increase the washing power of each bowl.



PATENT WOOL WASHING MACHINE BY JOHN & WM. MC NAUGHT. ROCHDALE.

FIG. 7.

[To face page 44.]

Back of
Foldout
Not Imaged

The third type is most useful for the treatment of clean wools, the forks being attached to an endless chain which runs round rollers at each end of the bowl. The motion is steady and continuous, making very little movement in the sud, except in the case of the machine made by Messrs. John Petrie, Jun., Ltd., where, as has already been stated, the forks are really used to retard the wool whilst the sud flows through it. All these types are in common use, and all have their advantages, but for ordinary medium qualities the second type is most often seen, and it might fairly be said to be the most popular.

No reader must regard this chapter as a comprehensive treatise on wool washing. A treatise regarding the impurities which are found on wool and the means adopted to remove them might be made to fill a volume, and as the subject is of less general interest to the woollen spinner than to the wool comber, only a short *résumé* of the subject has been given here. Readers more specially interested are referred to two chapters on "Principles of Wool-Combing," published by Messrs. George Bell & Sons.

CHAPTER III

CARBONIZING

WHEN raw or manufactured wool contains burrs, cotton, or other vegetable fibres, it is said to be carbonized when it is treated with sulphuric acid or other chemicals, in such a way as to destroy the undesirable vegetable matter and to leave the wool uninjured. The term is somewhat of a misnomer, for the vegetable matter is not burned, as it is called, nor are the hydrogen and oxygen all removed and the carbon left behind. All the various processes for carbonizing are very nearly alike, in that some part of the reagent employed, unites with some of the oxygen and hydrogen which go to compose the cellulose ($C_6H_{10}O_5$), leaving a portion of the water of hydration in less stable combination with the other constituents, so that the material, when subjected to severe drying, loses both oxygen and hydrogen, becoming a friable hydro-cellulose which falls to powder when subjected to beating, shaking, or any violent form of vibration.

The process of carbonizing may be applied to wool in three different stages of its manufacture—

First, on the raw material, after all grease and suint have been removed by washing. This is for the destruction of burrs and seeds.

Second, on rags, which may be called the raw material

of the shoddy trade, for the destruction of cotton which forms part of the fabric.

Third, on woven all-wool pieces, for the destruction of vegetable impurities contained in the cloth.

In this country, wool which is carbonized before carding, is nearly always washed before it goes to the acid bath; but even in so simple a matter as this no hard-and-fast rule can be laid down, because on the Continent they hold the *theory* that wool should be put through the carbonizing process before the grease is removed, in order that the grease may protect the fibres from the injurious action of the acid. It is very doubtful if any practical carbonizers adopt this method. We, on the other hand, remove the grease before treatment with acid, because it has a tendency to fasten the grease more permanently to the exterior of the fibre, making it very difficult to remove in the final washing, and more costly to neutralize in the alkali bath. This fact was well known as long ago as 1884, for McLaren wrote: "Experiments have been made to test this, and it has been found that the sulphuric acid, acting on imperfectly cleansed wool, sets free the fatty acids which fix themselves on the wool, and cannot be got rid of by any ordinary process." The acid will also attack the alkaline suint, making it not only impossible to recover this valuable by-product (carbonate of potassium), but destroying a quantity of acid in the process, and thereby adding to the cost of the carbonization.

There is little to be said regarding the treatment of rags in this process. They are carbonized after they have been sorted and shaken, for it is only in extreme cases that rags are considered dirty enough to be washed before being pulled. If such a lot were destined to be carbonized, they would be washed

before, and not after, the process, because if they were not washed, the impurities they contain would find their way into the acid bowls to the detriment of the bath. This must not be taken to mean that the average type of rags which are carbonized is a model of cleanliness; the best cast-off clothes are of course worse for wear, but on the other hand, very few rags are washed before they are made into shoddy. It is the exception rather than the rule to find washing bowls in a shoddy factory.

Woven pieces which are to be carbonized may be treated—

First, previous to milling;

Second, after milling;

or, after dyeing.

In order to get perfect regularity in the finished piece, milling should be done at the earliest possible stage after weaving, because faults may be remedied in subsequent finishing processes; but it is well known that soap is a necessity for milling, and as acid treatment causes the very opposite effects to those produced by soap, there is good reason to postpone carbonizing until the milling has been effected. If pieces are carbonized before milling, great care must be taken that the acid is completely removed from the thickest pieces, for if this is not done the acid will decompose the soap in the milling process, leaving free fatty acids which are of course highly detrimental to regularity of work.

If milling takes place before carbonizing, it is equally important that every atom of soap should be removed from the piece before it reaches the acid bath, or again the residue of acid will decompose the soap, leaving the oil or other fatty acids adhering to the piece. This will cause trouble in the dyeing, and there is also another drawback to this order of

events. Milling makes the fabric so thick and close that it is very difficult indeed to carbonize thoroughly, unless very severe treatment is applied, and such treatment is naturally injurious, undoing in part the result of the milling.

It is easy to see the advantage of carbonizing after milling. The goods mill more easily because they come softer to the machine, contracting more rapidly with proportionately little expense. If a piece is to have an acid dye, some authorities assert that carbonizing is best done after it has taken the colour, because, for reasons already given, uncarbonized goods dye much more level and with less tendency to spot than those which have already been acidified and baked.

By far the greatest drawback to carbonizing in the piece is the possibility of stains or even of holes, which may be caused by drops of condensed liquid falling from the roof of the drying chamber. The stains are worst of all if the roof should happen to be of iron. For this reason the ceilings of the ovens must never be neglected. All condensed liquid must be regularly cleaned away, and the whole kept as clean as circumstances will permit.

Before anything further is said, it ought to be clearly stated that carbonizing consists of five processes—

First, the exposure of the materials to the action of reagents, either gaseous or in solution, that will affect all vegetable matter, but will leave the wool entirely unaltered.

Second, the removal of every superfluous drop of acid by mechanical means.

Third, the drying of the material, which reduces the vegetable cellulose to a friable hydro-cellulose. This process may very seriously injure the wool fibre if the baking is not properly done.

Fourth, a crushing, beating, or other violent mechanical shaking process, to reduce the brittle hydro-cellulose to powder.

Fifth, a final rinsing, or process of neutralization, with mild alkali, in order that all remaining traces of acid may be removed.

By far the commonest of the reagents used to disintegrate the vegetable fibre in wool or woollen pieces is sulphuric acid, but it is by no means the only one. There are, in fact, two entirely different methods in use—the one dry, the other wet. In the dry method the wool and its impurities are exposed in a confined chamber to the action of hydrochloric acid gas for three to four hours; but as its production and use are more expensive and more troublesome than any of the wet processes, the advantages which are claimed for dry carbonizing are seldom considered for the treatment of wool. For the wet processes four reagents are in common use—

Sulphuric acid	.	.	H_2SO_4
Acid sulphate of soda	.	.	NaHSO_4
Aluminium chloride	.	.	Al_2Cl_6
Magnesium chloride	.	.	MgCl_2

All of them are employed in solutions the strength of which varies, and is ascertained in each case by the specific gravity of the liquid. This also varies considerably, according to the condition and nature of the material to be treated. For example, one writer gives a latitude of $3\frac{1}{2}^\circ$ Baumé (from $3\frac{1}{2}^\circ$ to 7°) in the strength of the liquid for carbonizing wool. This means that anything between $3\frac{1}{2}$ to 7 lbs. of acid may be added to every 100 lbs. of water (see Table IV., p. 51).

As a matter of fact, figures have to be used with the utmost caution in a case of this kind. The harder and larger the

pieces of vegetable matter are, the stronger must be the reagents or the longer the treatment. Cotton and burrs that are small, naturally require less acid and less drying than "hardheads" or similar seeds; but the practical man will remember that this kind of seed will fall out without any difficulty in the carding, and it is never worth while to risk injury to the wool in unnecessary attempts to turn them into powder. Although the use of hydrochloric acid gas is the only really dry process, users of the chlorides must remember that although they are used in solution, their action in theory is exactly that of the hydrochloric acid. As a matter of fact, they have no action on the vegetable matter themselves. They produce no effect until the temperature in the oven reaches a

TABLE IV.

HEATS AND DENSITIES FOR CARBONIZING.

(Heat in degrees Centigrade; density in degrees Beaumé.)

		English, 1881.	English, 1884.	German, 1904.	English, 1905.	American, 1906.
Sulphuric acid at 7s. cwt.	Density of bath .	4-5°	4-5°	3½-7°	3½-4°	3½-6°
	Heat for drying .	125-140°	122°	40-50°	80-85°	40-50°
	" baking	—	—	60-75°	—	60-80°
	Time required .	—	—	—	1½-2 hrs.	3-6 hrs.
Chloride of aluminium at 18s. cwt.	Density of bath .	—	6-7°	—	8°	6-7°
	Heat for drying .	—	100°	40-50°	100-105°	40-50°
	" baking	—	—	100-105°	—	150°
	Time required .	—	—	—	—	3-6 hrs.
Chloride of magnesium at 1s. 6d. cwt.	Density of bath .	—	—	—	8°	4½-7°
	Heat for drying .	—	—	—	100-115°	40-50°
	" baking	—	—	—	100-115°	150°
	Time required .	—	—	—	—	—
Bisulphate of soda at 4s. cwt.	Density of bath .	—	—	—	5-6°	6½°
	Heat for drying .	—	—	—	100°	100°
	" baking	—	—	—	100°	100°
	Time required .	—	—	—	¾ hr.	3-6 hrs.

point (it is over 100°) where the chlorides begin to give off hydrochloric acid. They are more often employed in the carbonization of cloth than for wool. Chloride of aluminium has a distinct advantage over chloride of magnesium, in that the hydrochloric acid is set free at $5-10^{\circ}$ lower than it is from the latter. Moreover, residual magnesium is just as injurious in the after-processes as is aluminium, and the chief advantage of the magnesium chloride therefore lies in its extreme solubility and cheapness. In America, a mixture of hydrochloric acid and sulphuric acid is sometimes used, but this is unusual.

There are few departments of the textile trade in which statistics are of less value to the practical man than they are in this particular process. The man who tries to work to the figures of others, without a practical knowledge of the work he has in hand, can never expect to obtain the best results. The fact that carbonized wool is so distrusted in the trade shows how little scientific treatment has been brought to bear upon it in the past. It is not necessary to damage the wool materially in any carbonizing process, and yet carbonized wool is always supposed to be hardened and roughened. It is not long since it was stated in print that sulphuric acid would destroy wool altogether. This is an entire mistake, unless the acid be heated; cold nitric acid will certainly dissolve wool very quickly, but wool may be steeped in the most concentrated sulphuric acid for any length of time. It is true that such treatment will raise the scale and harden the fibre, but a solution of acid and water may be made strong enough to dissolve silk without materially affecting the nature of wool stockinette, or tendering it sufficiently to render it useless. Such a solution would be about 80° Twaddell, and when we

remember that the usual strength of carbonizing liquor is only from 2 to 4° on the same scale, we need not be surprised to read in McLaren that "when carbonized wool is examined under the microscope the scales and serrations are found to be as perfect as those of the same wool not treated by the process." In addition to this microscopic evidence, it was long ago proved by Weisner that wool from the Angora goat, when steeped in an acid bath of 4 per cent. or 5¼° Twaddel, actually increased in tensile strength from 480 to 568 grains, after heating to 60-65° C. It was only when the acid strength was raised to 7 per cent., or nearly 10° Twaddel that the wool showed any signs of weakening.

This ought to be proof enough that wool need not be ruined if properly carbonized, but the man who wishes to be a successful carbonizer must always keep two things in view.

In the first place, he must see that the vegetable matter is reduced to powder with the least possible effect on the fibres and the nature of his wool.

In the second, he must contrive to obtain this result with the least possible expenditure on acids and on alkalies to neutralize them.

Fortunately, these two ends are in no way antagonistic, for the man who destroys his burrs with the least amount of acid and the lowest heat, is generally the man who turns out the most satisfactory finished article.

A great saving in wages, as well as considerable saving in acid, may of course be effected by the use of well-designed and well-arranged plant. In old-fashioned systems the wooden or leaden acid tanks, which stood upon the floor, were large, and often circular in shape. Into them the wool or rags were pressed. This was by no means easy, for dry rags and dry wool

are very hard to submerge until they are thoroughly saturated with liquid, and the modern plan of sinking the tanks into the floor, like tan pits, makes the work of submerging the material much easier. Then, in the old-time method, the dripping rags or wool were lifted piecemeal from the vat by hand or forks, and either left to drain on racks fixed for that purpose, or carried off in tubs to the hydro extractor or whizzer. In either case no small amount of acid runs, or is splashed away, and so is wasted.

A perfect system makes this impossible, and saves much labour. Each acid tank or pit T (Fig. 9), whose upper lip is level with the floor, contains a heavy wooden crate or basket lining C, fitting loosely within it. Into this the rags or wool are pressed. There they are left to steep until the burrs and cotton are thoroughly saturated with acid. A travelling crane is then swung above the tank, and the basket is hoisted well above the level of the floor, directly over the tank itself. There it is left to hang until the superfluous liquid has run off. Then, by a single movement, it goes bodily to the hydro extractor W, and when the movable bottom of the crate is released, the whole of its contents are tipped into the basket of the whizzer. The liquor from the whizzer, which, of course, stands upon the floor, runs straight back to the tanks, and even if some wool were dropped in transit from the tank, or dropped outside the whizzer, all the acid it contained should drain back to the tanks, because, like them, the floors should be all laid sloping towards the tanks. Such plant will save both labour and material, and if the number and size of tanks are in proportion to the whizzer, the drying and neutralizing plant, a continual supply may be kept up, and all waiting avoided. This will, of course, save wages.

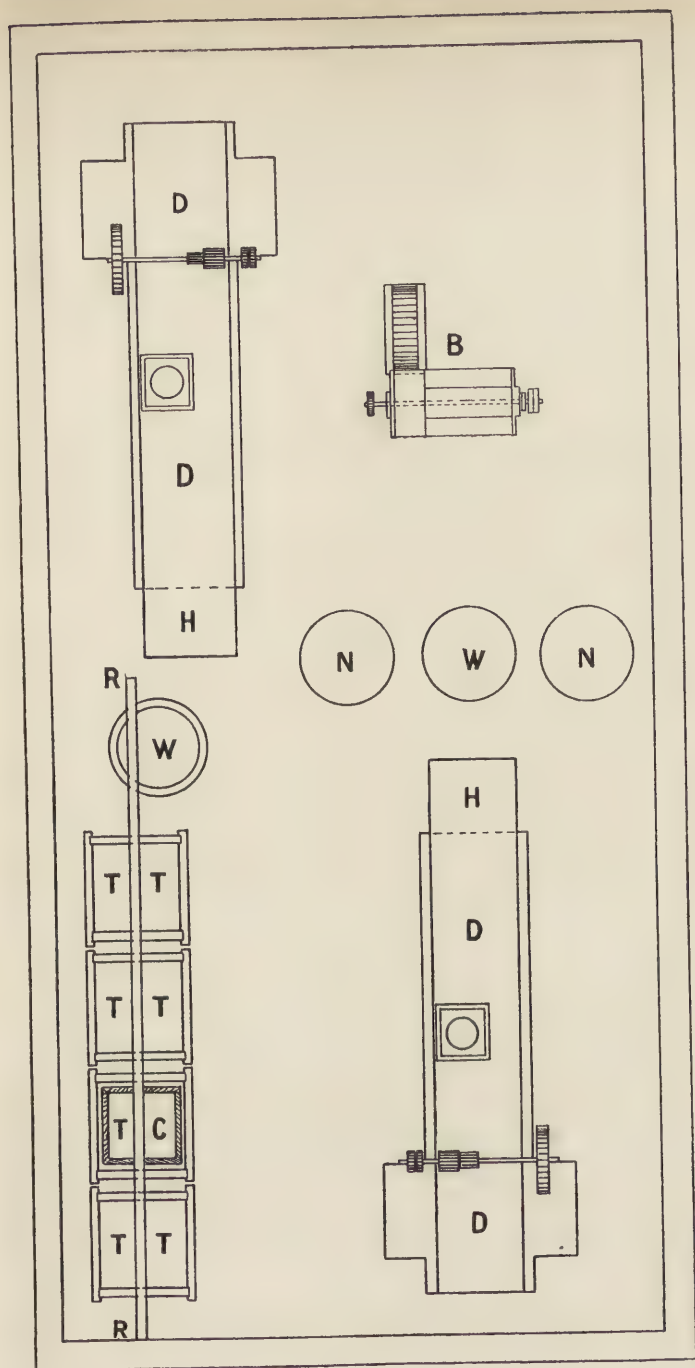


FIG. 9.

TT. Acidsteeping tank. C. Wooden crate in tank. RR. Rail on which
 crates are run to the whizzer W. H. Hopper feed to dryers DD, DD.
 B. Burr crusher. NWN. Neutralizing tanks and whizzer.

It is stated in the following chapter that shoddy has come to stay. Carbonizing is also a permanent institution, and, unlike the pulling of rags, its results are likely to improve materially through the work of scientific investigators. Carbonizing, like the shoddy trade, has always had its bitter enemies, but wise men like Bramwell and McLaren saw, nearly thirty years ago, that there were wonderful possibilities in the extracting process. Ever since their day, scientific and practical chemists have been working to reduce the strength of the reagents and the height of the temperature, in order to destroy the vegetable matter by means that are absolutely non-injurious to wool. Thirty-eight years ago 250° F. (or 122° C.) were considered necessary to carbonize the burr, and the only wonder was that the wool which was treated to such temperature was ever fit for use of any kind. It was 38° above boiling point. Now we think that 32° below the boiling point is high enough; we also take good care to draw away the acid moisture as it forms. Sulphuric acid was the only reagent then in regular use, and even as much as 9 per cent. was added to the bath. Five per cent. seems to have been the quantity in general use ($4-5^{\circ}$ Bé), and it must be confessed that in this respect practice is still erratic. But on the other hand, reagents other than H_2SO_4 are steadily increasing in popularity, the newest of them being, perhaps, the best worthy of description. In Spennarth's process a solution of bisulphate of soda is used instead of sulphuric acid, but its specific gravity is relatively denser: 10 per cent. T or 67 per cent. Bé is considered necessary. The much less drastic action of the salt also makes a longer immersion necessary. When the vegetable matter is thoroughly saturated, the wool is taken to the hydro-extractor, and all superfluous liquor completely removed before

it goes to the stoves, where it is treated at steadily increasing temperatures in a series of ovens, the last of which is maintained at 100° C.

One advantage of this process shows very clearly with pure white wool goods; for the white vegetable matter like cotton is rendered friable without being turned dark brown, and the colour of the finished article is in no way impaired. Moreover, the bisulphide bath is said actually to add nature and tenacity to the fibre, and to be particularly advantageous for "open wool." It is not yet in use on a large scale in this country, and this may be due to the fact that burrs regain some of their tenacity, and do not fall to pieces in the breaker, if they are not treated immediately they come from the dryer; but this is a defect which should be easily remedied. Even if the process is not all that is claimed for it, it is one which deserves practical application on a business footing. Aluminium chloride was known as a possible substitute for H_2SO_4 when McLaren wrote in 1884, and since his time, a corresponding salt of magnesium has been very often used. It has already been explained that both these salts when in solution are entirely inactive until raised to one or two degrees above the boiling point. At that temperature they give off HCl , and it is this acid gas that acts upon the cellulose. In theory, therefore, the action of the chloride salts may be called a dry process, for they resemble the HCl method in the manner in which the vegetable matter is transformed into brittle hydro-cellulose.

It is quite impossible to estimate how much the various reagents are used in practice, for men who make a success of a new method are very seldom inclined to make the fact public. Sulphuric acid carbonizing is to be seen every day, and is

almost universal for wool and rags. The chlorides are always spoken of in reference to cloth, and for that purpose they have their advantages; but they also have their drawbacks, which are apt to be the more injurious just because they are not very noticeable. The caustic nature of oil of vitriol in its concentrated form is ever in the mind of people who use it, but it often escapes their notice that the same acid in weak solution is given as a medicine for certain ailments. It is probably a vague fear of some obscure action on the part of this powerful acid that has led to the use of the more expensive aluminium chlorides in its place. True, they are easier to handle, but if every trace is not removed from the cloth before any soap is applied, either aluminium or magnesium will unite with the fat acid, to form mineral soaps of an insoluble nature, which are certain to lead to stains in the finished piece. The same thing will happen if there is the smallest quantity of oil on the piece when it goes to the chloride bath.

These aluminium and magnesium soaps are very similar in constitution to the lime soap which is formed by the use of soap in hard water, and it is safe to say that those who are acquainted with the nature and tenacity of the one, will be in no hurry to make the acquaintance of the other members of the family.

The questions as to the length of time, and the temperature to which the acidified material should be exposed, are of the greatest moment, and to this end the object of the drying must be always kept in view. The common view that it is a baking process in conjunction with the caustic nature of the acid that "burns up the burrs" is wholly incorrect. With sulphuric acid the process is simply a means of drying out the superfluous water from the moist cellulose until the vegetable material is

reduced to hydrocellulose which is supposed to consist of $C_{12}H_{22}O_{11}$. It is a very unstable chemical combination; it is extremely brittle, and easy to pulverize. But the nature of the chemical action is so obscure that specialist chemists do not agree about it. The drying should be done at such a temperature that the wool is neither injured nor turned yellow. It can be done at very low temperatures if sufficient time is given. To get the greatest efficiency at low temperatures, provision must be made for the escape of the water which evaporates in the process. For example, the application of free steam into the oven would of course be fatal to the whole process.

The original system of drying, which is still much in vogue, took place in a single oven or set of separate chambers of large dimensions. Into these chambers the acidified material was placed in thick layers on shelves or racks direct from the hydro extractor. The doors were then closed, and by means of furnaces or by means of steam, the temperature was raised to boiling point, or over. The moisture in the wool was consequently evaporated rapidly or even turned to steam. In either case the wool was left in contact with moisture at very high temperature for a considerable time. This is well known to be detrimental to the wool, and as the acid fumes are unable to get away they act upon the wool. They also condense on the roof of the chamber in the form of a thick liquid which accumulates in drops and falls in time upon the material which is undergoing treatment. These drops are so strongly acid that they act upon the wool or cloth, and either stain it badly or actually burn it into holes.

There are two ways to obviate these disadvantages. Either the ovens must be ventilated very thoroughly, so that all vapour is drawn off by fans as soon as it is formed, or two ovens must

be used for every lot, the first one being used for drying only, with a low temperature but plenty of ventilation; the second one for raising the temperature of the dried material just high enough to complete the alteration of the acidified cellulose or vegetable material. To obtain these ends in furnace-heated ovens would require an extravagant expenditure of fuel, and they are therefore confined to the treatment of rags for shoddy, because extract or alpaca made from them is never expected to spin to fine counts; cheapness is of more value than in any other branch of the trade, and the single chamber process is often considered good enough.

From force of circumstances iron is very largely used in the construction of the oven, and its roof is often supported by iron beams. However well these beams are protected by paint the heat and the acid fumes soon eat it off and attack the iron itself. It is then that the greatest damage will take place. The acid, the heat, and the moisture produce a coat of rust, which mingles freely in the drops that form, and drip upon the wool, so that iron stains are formed on anything they come in contact with.

It was to obviate these faults, and injury to plant caused in this way, that machine dryers were introduced. Very many variations of the same type are now in use.

It is easy to see that means which are most suitable for the treatment of wool and for carbonizing vegetable matter are entirely at variance, and in the nature of things it is necessary that the machines should be worked with both ends in view. For example, all modern authorities agree that 50° C. is the highest temperature to which the acidified wool should be raised until all the superfluous moisture is driven off, but there are very varied opinions as to the best temperature for the

final process. It is a question of time *versus* temperature; if long enough time is given, any man can demonstrate for himself that a low density solution and a low temperature will alter the cellulose effectively, and it goes without saying that the lower the temperature the better will the wool be.

Vegetable material will carbonize completely in a really dry atmosphere at 60-70° F. (or 15-20° C.), if it is left for twenty-four hours or more, but this of course would need an immense amount of room where a large amount of work was being done, and it can hardly be described as a practical method; but, on the other hand, any wool so treated would be in first-class order when the process was complete, and the object of every carbonizer should be to approach these figures as nearly as possible. On the Continent some carbonizers consider 75° C. to be the highest figure that should be touched, and a recent writer in "The Textile Manufacturer" recommends 2-2½ hours at 80-85° C. as being far preferable to 90-95° for an hour or for three-quarters. It is the most modern American practice to keep the temperature below 170° F. These figures all relate to the sulphuric acid process, and more will be said regarding other reagents later; but the necessity for a low temperature in the drying process makes it imperative that machines employed in drying carbonized material should be constructed in such a way that the hot air will reach the driest fibres first; in other words, the material in the machine should travel against the air current, not with it, for if that plan is adopted the bulk of the vapour will be removed at a low temperature, and the material will be almost dry before it reaches the maximum. If it is considered essential that a plant should be equipped with machine drying, the most scientific method would be to use two small machines instead of one large

enough both to dry and bake the vegetable matter. In this way the air at 80° C. might be passed through the baking machine first and then reduced in temperature before the same air was turned into the drying machine. But, curiously enough, there is a tendency in these days to return to a modification of the drying oven, instead of the drying machine, simply because it can be made to give any desired temperature for any length of time at any period during the process.

A set of ovens for this type of work may be of almost any size or shape. They must be so arranged that the heat of the air as it enters the first one must never exceed the safe maximum for the class of work in hand. It must also be possible for the air to be turned into the ovens in any order and brought to bear on the wettest wool when it has reached its lowest temperature. If the ovens are deep and long, the trays that they contain will necessarily be so long also that they must be drawn out to be filled: but if suitable arrangements are made for hauling them out, the cost of drying in wages and steam is little higher than in the continuous machine, and the treatment of the material is distinctly superior.

When the wool or pieces or rags are taken from the oven or other form of drier, the vegetable matter is, or ought to be, completely carbonized; that is to say, the constitution of the material is completely altered, the outward form remains the same, but the structure has ceased to be fibrous and of great tensile strength, and has become extremely brittle and liable to disintegrate. Cotton may actually go to pieces as the rags that contained it are removed from the oven, but the burrs and hardheads are often still hard when they are completely carbonized, though they only require a crushing process to reduce them to powder.

Before the burrs can be properly pulverized by heavy rollers, it is necessary that the wool which contains them shall be spread in a thin and uniform layer, so that it may go between the crushing rollers without the individual fibres being damaged by their weight, whilst the larger burrs are ground to powder.

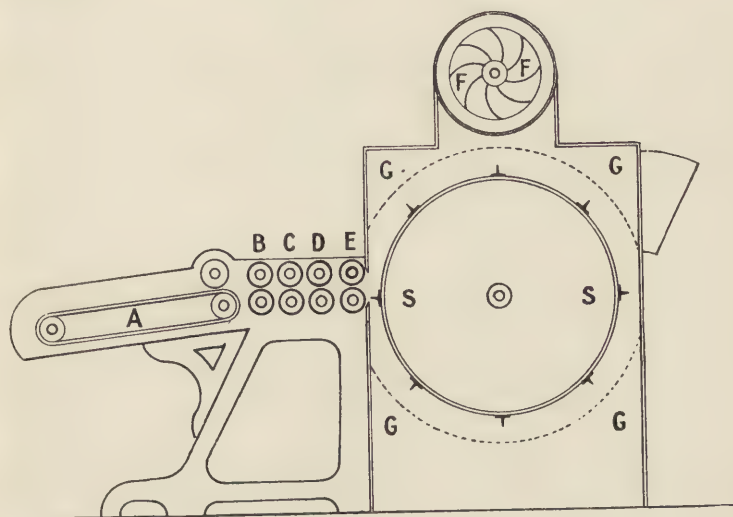


FIG. 10.—SPIRAL VANE WILLEY.

A. Feed sheet.

B, C, D, E. 1st, 2nd, 3rd and 4th pairs of crushing rollers.

S. Swift or beater.

GG. Grid through which dust and powdered cellulose is drawn by the fan F.

In principle the machine resembles a worsted drawing-box, because a thick layer of wool goes up to the first pair of rollers by which it is reduced in thickness and extended in length by drafting. This pair of rollers run slowly with about one half the surface speed of the second pair, which in their turn are overrun by the pair that follow them (see Fig. 10). This is really a process of drafting, and is unlike anything else of the kind in the woollen trade, although it is one of the most

familiar operations in worsted spinning. As the layer of wool goes through each succeeding pair of rollers it is doubled in length and halved in thickness, so that if there are four pairs it should emerge from the last roller in a very thin but fairly uniform ribbon in which the burrs are conspicuous, being thicker than the wool which surrounds them. As the burrs and the wool go between the heavy rollers the burrs are consequently crushed to powder, whilst the thin layer of wool escapes. If it were possible for the roller surfaces actually to touch one another, the wool also might be crushed to pieces, but they are generally so arranged that there is a space of $\frac{1}{1000}$ inch or more between their surfaces, and through this small space the wool escapes uninjured.

To carbonize a piece of cashmere cloth, in which the warp is cotton and the weft is wool, is a very pretty laboratory experiment. For such a purpose there is no need to use the weakest possible solution or the lowest temperature. With five per cent. solution of H_2SO_4 for one hour, and a similar time in an oven at 100°C ., the cotton is rendered so black that the twill of the weave shows with the utmost distinctness, until the fabric is twisted, rubbed, or violently shaken. As if by magic the warp then disappears, and only a bundle of detached threads remains in the hand.

A comparison with the bisulphate of soda process may be very simply made by baking samples of the same cloth, steeped in the two different liquids, in the same oven. As is stated elsewhere, the acid sulphate affects the colour of the cotton very little. The cloth remains almost unchanged in appearance, but the cotton is equally brittle although it is not blackened, and the cloth will fall to pieces exactly like the sample that was treated with sulphuric acid.

If the oven be raised to 105° C., any sample that has been treated with aluminium chloride will be equally brittle in a little longer period, whereas the temperature must be 106–110° to thoroughly carbonize cotton with magnesium chloride. This small experiment is mentioned here because it shows so plainly the nature of the treatment which is necessary to pulverize the carbonized cotton. A lesson may be learned from it. Compression or torsion affect the cotton in such a way that less violent shaking will completely remove it from the cloth, and the shaking machine should therefore be so set that the burrs may first be crushed or twisted before any attempt is made to shake them from the wool. If the machine is not well adjusted in this respect, such violent shaking or beating would be necessary that the wool would either be tangled or broken in the process, and the fault would be attributed to carbonizing.

It is for this reason that the wool with the burrs in it must go through the crushing rollers before they reach the part of the machine that is to shake out the carbonized vegetable matter, where not only burrs but also straws and hemp will disappear as fine dust. It will of course happen at times that bits of wool have gone to the acid bath so packed with burrs that they are not rendered so brittle as to fall to powder in the shaker. In extreme cases there may be lumps so dense that their centres are quite unaffected by the process. Burrs from such lumps will of course come out in their typical form as long barbed fibres, and will do a great deal of damage. Even if all the burrs are partially carbonized the faults will be serious enough. They will not fall to powder in the breaker, but will probably be broken into small pieces which will be fairly tenacious. Many of these will be so small that they

will fall out in carding, but others will go through to the condenser, and will therefore appear in the yarn. To ensure that all burrs may be attacked by the acid, it is therefore necessary for the wool to be thoroughly opened or willeyed before or after washing. In practice it will of course be willeyed before washing, for the opening which makes it possible for the acid to attack the burrs also affects the wool in such a way that less soap and less heat are needed to cleanse it in the washing-bowls.

It is therefore necessary that the crushing and beating machinery should be watched as carefully as all the other details of carbonizing; and because the wool is still acidified, it must be taken from the shaker to the washing-bath with the least possible delay.

The final process with which a carbonizing plant must be equipped is that of neutralizing. The acid remaining on the wool must be removed by washing, or, more correctly speaking, as much as possible must be removed by washing in clear water, and what acid then remains must be neutralized by a bath containing some suitable alkali. Carbonate of soda and carbonate of potassium are most likely to be selected, as being cheap in proportion to their efficiency. Expressed in everyday language, the alkali will destroy the acid. More correctly stated, the acid and the alkali will combine to form a neutral salt, and at the same time there will be water and carbonic acid gas set free. The point of the argument is obvious.

The acid is expensive, and all that is removed from the wool before it is dried may be used over again in the steeping tanks. That which is washed out in the water bath is usually wasted, although arrangements might be made to purify it and use it for steeping; but such acid as goes to the neutralizing

tank is not only wasted, but costs money by destroying carbonate of soda. This is a good reason for washing out all possible acid in the steeping-bowl.

The greatest difficulty which stands in the way of attaining this end with washing bowls is due to the rollers. If simple tanks and a whizzer are used, the wages bill will be rather larger, but if wool is going to be dyed before carding, there is no need to use any alkali if a sufficient quantity of water is allowed to flow through the tank full of wool, entering at the bottom, and flowing away from the top (see NN, Fig. 9). However, if the wool is to be neutralized, the process must begin with warm water, which may, if convenient, be reduced in temperature as the process continues. Sudden changes of temperature are injurious to the wool, and if whilst hot it is suddenly immersed in cold water, it will tend to harden and stiffen the fibre. It is therefore customary, when dealing with open wool, to use a set of ordinary washing bowls with squeeze rollers to press out the liquid. In the first bowl there is tepid water, which is continually being renewed. In the second is an alkaline solution, and in the third or last is the soap, which gives a "lofty" feeling to the finished product. When rollers have to deal with wool as it comes from suds, almost any pressure may be applied to the upper roller (see A, Fig. 7) without damaging the fibre. This is due entirely to the lubricating properties of the soap, but when the same rollers have to press the liquid from wool emerging from an acid bath, they can never be worked with relative efficiency, because the lubricant is absent; the acid tends to harden the wool so much that the fibre will cut to pieces if sufficient weight is applied to squeeze the wool thoroughly dry.

Of course, the water in the lowest bowl gets more and more

acidified as time goes on, and when it is relatively strong, the small quantity of it which goes through the rollers with the wool is quite sufficient to destroy a lot of alkali.

TABLE V.
SPECIFIC GRAVITIES AND EQUIVALENT DEGREES BAUMÉ AND TWADDEL.

Degrees Twaddle.	Degrees Baumé	Specific Gravity at 15° C.	Percentage H_2SO_4 .	Percentage $NaHSO_4$.	Percentage Al_2Cl_6 .	Percentage $MgCl_2$.
0	0	1.000	0.09	—	—	—
1	0.7	1.005	0.83	0.9	—	—
2	1.4	1.010	1.57	1.8	—	2.0
3	2.1	1.015	2.30	—	4.0	—
4	2.7	1.020	3.03	3.0	—	4.2
5	3.4	1.025	3.76	3.8	—	—
6	4.1	1.030	4.49	4.7	8.0	6.5
7	4.7	1.035	5.23	5.5	—	—
8	5.4	1.040	5.96	—	—	—
9	6.0	1.045	6.67	—	—	10.0
10	6.7	1.050	7.37	8.0	—	—
11	7.4	1.055	8.07	—	—	11.1
12	8.0	1.060	8.77	—	—	—
20	13.0	1.100	14.35	—	—	—
30	18.8	1.150	20.91	—	—	—
40	24.0	1.200	27.32	—	—	—
50	28.8	1.250	33.43	—	—	—
60	33.3	1.300	39.19	—	—	—
70	37.4	1.350	44.82	—	—	—
80	41.2	1.400	50.11	—	—	—
90	44.8	1.450	55.30	—	—	—
100	48.1	1.500	59.73	—	—	—
110	51.5	1.550	64.67	—	—	—
120	54.1	1.600	68.51	—	—	—
130	56.9	1.650	72.82	—	—	—
140	59.5	1.700	77.17	—	—	—
150	61.8	1.750	81.56	—	—	—
160	64.2	1.800	86.90	—	—	—
168	—	1.8385	99.00	—	—	—
—	—	1.840	100 pure	—	—	—

The master must decide for himself whether it will pay to use a lot of water, or a relatively large amount of alkali. One or the other is necessary, for the wool must have no trace of acid on it when it reaches the final bowl containing soap. If acid should reach the soap, the latter will be decomposed, and

the wool will go forward to the cards with free fatty acids present, instead of an emulsion of pure neutral soap.

It is pretty certain that the deposition of decomposed soap would never be regular. Some portions of the wool would absorb a larger share than others, and as the fatty matter would seriously affect the dyeing, the irregularity would show as uneven colouring when the wool was manufactured and dyed. This, again, is a fault that would be put down to carbonizing, although it would be due to nothing but carelessness or ignorance on the part of the washer.

When the wool emerges from the pressing rollers that remove the suds and return them to the bowl, all the processes which are incidental to carbonizing are complete. The wool is, or should be, in an exactly similar condition to that of uncarbonized material as it comes from the rollers of the last bowl of a set of washing machinery. It is not therefore necessary to say anything more as to the drying process, which has already been dealt with in detail in this chapter.

In some establishments the wool is caught by a fan immediately it leaves the nip of the rollers, and is opened and dried by the beating it receives as it is thrown on to the pile in the bin provided for it. In others it is thought necessary to dry the wool by steam heat either in continuous drying machines (see plan, Fig. 9) or on drying frames. Such a system is more necessary in the woollen than in the worsted trade, for the different character of the wool employed in the two makes it desirable to submit the shorter and more felted kind to one or more opening processes before it reaches the carding or scribbling machines. These processes are intended to shake out any remaining dust, and that result is more readily attained when the wool is quite dry. Wool for worsted yarn

could not be carded without serious loss, if it were freed from all moisture. It only receives about 3 per cent. of oil, but, on the other hand, an oiling process forms a prominent feature in most woollen factories, and an amount of oil is applied that is often nearly equal to the total of both oil and moisture present in a worsted top: two gallons per 100 lbs. being equal to 18 per cent.

CHAPTER IV

SHODDY

IT is a matter for profound regret that the three great textile industries of Lancashire and Yorkshire do not work in closer touch with one another. The average worsted man knows little of the methods adopted in the spinning of woollens, and cares nothing for the principles involved in that trade. Few woollen spinners make themselves acquainted with the theories of the worsted or the cotton trades, but, if we may judge of the sale of worsted books in Lancashire, the same taunt cannot be thrown against workers in cotton. The science of the cotton trade was first discussed by Evan Leigh in 1882, and since his day a series of highly technical workers have followed in his wake. Such work is never thrown away, and the cotton trade is reaping the reward. Unfortunately for the woollen and worsted industries, the time has not yet come when the study of science is considered necessary in connection with them. It is not in the cotton trade that we are interested at present; we can find how things stand much nearer home. For example, "shoddy" is still a term of reproach in Yorkshire, and this fact alone proves the ignorance of the county regarding one of its staple industries. The fact is, that very few people outside the woollen trade know what shoddy really is; know what an infinite variety of sorts there are, how they are treated, and for what they are used.

Shoddy, in text-books, is always understood to mean the

fibrous substance which results from the "pulling" or beating to pieces of soft hosiery, of dress goods and of many of the looser kinds of worsted fabrics. In other and more technical terms—

Shoddy is the product of unmilled fabrics.

Mungo is the product of all kinds of fabrics that have been milled in manufacturing.

Mungo is shorter, and usually finer in quality than shoddy, because, in the first place, milled cloths are nearly always made from shorter kinds of wool; and secondly, because the fibres of a milled cloth are very difficult to separate from one another. They are therefore always considerably broken in the process of pulling. Both mungo and shoddy are rather generic terms, than names of any special kind of material; for both classes have an infinite number of special divisions with very different names under which the various kinds are offered on the market. Such names as worsted, serge, flannel, and merino are a few of those which play their part in the heavy woollen trade.

"**Extract**" still remains (in books at least) a third generic term to indicate a special class. It covers every length and quality of pulled material, whether of milled or unmilled origin, and always means that the cloth from which it came was partly composed of cotton which has been destroyed by the treatment which is always known as carbonizing.

Merino may or may not be carbonized. There is no cotton in the cloth from which it is made; but it is sometimes carbonized instead of being "seamed" to destroy the cotton thread used in the sewing of the garments.

Shoddy, mungo, and extract must all go through at least seven processes before they are again in the form of fabric.

They may go through all of these alone, but much more often they are blended with other materials between the third and fourth operations. They are—

First, shaken to remove loose dust and dirt.

Second, sorted into many shades and qualities.

Third, pulled. This is the operation that reduces the rags to their original condition of yarn or fibres.

Fourth, carded, to separate every thread into fibres.

Fifth, condensed, to complete the carding process and arrange the fibres in narrow strips or ribbands ready for spinning.

Sixth, spun on mules, or occasionally on frames.

Seventh, woven.

In many cases the rags will go through extracting, dyeing, garnetting, and blending, in addition to the above processes, and there are exceptional instances, in which they will also be washed or willeyed, or both.

It will come as a surprise to many people to hear that England imported 91,000,000 lbs. of material for the production of shoddy in 1905, and that quite double that amount is actually put into work each year. Doubtless, also, it will come as a shock to the wearers of expensive smoking-jackets to learn that the cloth from which such garments are made, is faced with this despised material. This fact was sworn to at an important trade inquiry in Washington in 1903.

Shoddy has come to stay. It has already been in use for one hundred years, and it behoves those who wish to stop the use of worthless and injurious materials to understand their subject, before they declaim in general against a trade which is so large and varied. In 1905 the woollen materials used for shoddy amounted to more than one-third of the total wool

imported into this country, and to very nearly half of all the foreign wool manufactured by us, for we re-export over 200,000,000 lbs. in addition to a large amount of the wool which is grown at home. The amount is largely in excess of all the wool grown in the British Isles, and if we compare the figures for 1905 with those of five years previous, we find that the proportion of rag wool to the new wool which was put into consumption is steadily on the increase, the figures given for 1899 being 125 millions of shoddy used against 520 millions of raw wool.

TABLE VI.

IMPORTS OF WOOL AND SHODDY (OR RAGS) IN POUNDS.

Year.	Total from British possessions.	Gross total wool imports.	Wool re-exported.	Wool retained for use.	Shoddy materials imported.
1850	44,709,000	74,326,000	14,388,000	59,938,000	(no record)
1855	60,217,000	99,300,000	29,453,000	69,846,000	"
1860	75,740,000	148,396,000	30,761,000	117,634,000	16,824,000
1865	138,954,000	212,206,000	82,444,000	129,761,000	32,670,400
1870	207,866,000	263,250,000	92,542,000	170,708,000	38,555,400
1875	282,743,000	365,065,000	172,075,000	192,990,000	56,929,600
1880	352,011,000	463,508,000	237,408,000	226,100,000	92,433,600
1885	404,576,000	505,687,000	267,501,000	238,185,000	73,133,600
1890	542,304,000	633,028,000	340,712,000	292,318,000	77,638,400
1895	660,046,000	775,379,000	404,935,000	370,443,000	84,257,600
1900	454,208,000	558,950,000	196,207,000	362,743,000	68,757,800
1905	503,944,000	620,350,000	277,864,000	342,486,000	91,932,800

The earliest history of the shoddy trade is obscure; but in 1860 it was believed that a man named Benjamin Law, of Batley, was the first to introduce machines for the opening of laps and thrums and knitted waste. This was in 1813. Previous to that day all kinds of woollen waste were practically valueless. No one could use it. It was usually left to rot, or dug into the fields or burnt. It seems that no patent was ever taken out for machinery to "pull" or open woollen rags, but

on their introduction every one worked as secretly as possible ; buying a very cheap commodity and turning out material that would spin to quite good yarn. It is clear that two machines began to run at Howley Mill, and one or two in premises in Scotchman Lane in Batley almost simultaneously, in 1813. Doubtless it must have been a profitable game, and as there was no patent to secure the exclusive use of the machinery to any one, the strictest secrecy was practised, and no one was allowed to see what was going on in the new industry.

Some people say that Brighouse had machines as early, if not earlier than any place in Yorkshire, and circumstantial tales are told about a Batley merchant who had his thrums and worsted waste ground into flocks at Brighouse. He made a journey to this neighbouring town, where he managed to obtain a glimpse "of those jealously guarded treasures whereby he was enabled to explain to the machinist who accompanied him, but who was not permitted to see the machines, the plan of their construction sufficient to guide the machinist, after encountering some practical difficulty, in producing the required copy." This is Jubb's description of the origin of the first Batley machines, and he tells us in addition that rag machines were in use in London prior to their being adopted in this part of the country, and that they were employed in making flocks for saddlery and for upholstery purposes. Probably the idea of pulling woollen rags was first derived from the practice of grinding linen and cotton rags for the manufacture of paper.

These early machines seem to have been of very large dimensions, with swifts of something like 50 inches in diameter, running at a very high velocity. Instead of having pegs in its periphery, the swift was set with plates, cut into teeth upon their outer edge, like doffing combs. Some of the earliest

users tried to drive machines like this by manual labour, but any one who knows the power required to drive a rag machine, will understand how far they failed. Horse-gins were also tried, but when the users realized that 600 or 700 revolutions per minute were necessary for their purpose, they very wisely took to water power.

By 1858, fifty machines like this were hard at work in Batley only. In the immediate neighbourhood there were as many more, and scattered up and down in various districts outside the radius in question, at least another fifty. If each machine ground up four packs per day, the total would account for 51 million lbs. of rags per annum, a quantity that, reckoning a loss of 25 per cent., would yield 38 million lbs. of clean rag wool, as it was then called. What had been previously done with all the woollen waste we do not know, but it is fairly safe to infer that much of it was left to rot, and a large quantity of rags were burned, for an old worthy, struck by the economic value of the trade, remarked, "Not a single thing belonging to the rag and shoddy system is valueless or useless. There are no accumulations of mountains of *débris* to disfigure the landscape; all, good, bad, and indifferent, pass on and are beneficially appropriated." Further, when speaking of the £700,000 sterling that would be realized for the one year's output, he says, "the greater part of it represents what has been paid for labour," inferring thereby that the cost of raw material was practically nil.

It must be clear to every one that the use of waste as compared with the destruction of waste is economically advantageous; such a point needs no argument. Unfortunately, however, denunciation of the fiercest kind has been heaped upon the shoddy trade from 1840 onwards, although

proof of any evils that it has brought in its train have very seldom been forthcoming. Shoddy was known as "devil's dust" for many years before the seventies. It was an epithet applied by Mr. Ferrand, a gentleman who laboured with the utmost earnestness, if not discretion, to destroy the growing trade of Batley and its neighbourhood. The phrase was one that fitted with the public taste; it caught the public ear, and long remained in use by professional agitators who took their part in the exciting and perilous times that followed for the trade. As is often the case to-day, they were bold enough to prophesy falsely concerning things they wished and hoped to see, and one of them named Stephen made use of the phrase—

"Mungo! thy days are numbered."

Of course he did not live to see his prophecy fulfilled, for we may reckon that without exaggeration fifty times more mungo is being used to-day than when he spoke.

It would be waste of time even to outline all the various agitations that have taken place against the rag-wool trade. But as a proof that this opposition to the use of re-made wool is not yet dead, some reference to the Conference in Washington in 1903 is of great interest. It met to discuss the Grosvenor Shoddy Bill, promoted in the United States about that date, and it brought to light not only many interesting facts regarding the uses to which shoddy goes, but it also exposed the bigotry that still exists in many quarters, particularly amongst the sheep ranchers of the West.

Some of the representatives of the wool growers confessed that "they knew nothing of the technical questions involved in the Bill," one of them admitting that "undoubtedly it is sentiment, and purely sentiment, which causes the people of the West to favour some kind of shoddy legislation." The

ranchers thought that a total prohibition of the use of shoddy would automatically increase the value of their wool, and two or three extracts from the Bill are quoted lower down to show the length to which prejudice may be carried. They fairly represent the tenor of the various clauses of the Bill, and it is much to the credit of all parties who took part in that conference, that the Bill was finally dropped. Its supporters were made to see how utterly impossible it is to draw a line between new wool and that which has been previously used. The situation was discussed with sanity and moderation by both parties, and the manufacturers' secretary was able to report when he got back home that—

“The discussion finally resulted in a promise on the part of your Committee to procure copies of the English Merchandise Marks Act, and of English laws relating to kindred questions, and to see whether suggestions can be made for a similar Bill . . . that may provide a remedy for any fraud practised on an ignorant buyer.” The Conference was thus a great success to the woollen manufacturers. The Bill was dropped largely on account of the friendly and often humorous method in which the Conference was conducted. Artemus Ward was quoted by one man to emphasize his point. He wished to make it clear that people often spoke of things they did not understand, and used the words, “It is better not to know too many things than to know so many things that are not so.” This was a piece of advice that might well find application in the Textile Trades regarding shoddy—and regarding many other things. Another delegate professed his entire willingness to eat a Chicago sausage or Hamburg steak so long as he was ignorant of its contents, but stated with a great show of truth that a sausage with a label giving details of all that it contained

would be an unsaleable commodity. The object of his argument was plain enough—he meant that it is absolutely unnecessary, and seldom even desirable, for retail users to know the origin of all the components of their food or of their clothes. If a Government has sufficient power of factory inspection to ensure that nothing harmful to the public is allowed to leave the works, there is very little cause for any one to complain of injury from the shoddy trade. Such a course of procedure would be very different from the tyrannical inspection that would have been imperative to secure the working of the Grosvenor Bill.¹ As it was framed it was wholly incompatible

¹ EXTRACTS FROM THE GROSVENOR SHODDY BILL OF 1901.

SECTION I.—For the purposes of this Act, the woollens or woollen goods or fabrics shall be understood to mean fabrics made wholly of sheep's wool, which has not been previously used in the manufacture or any of the processes of manufacture of any other article.

SECTION II.—For the purposes of this Act, the word "shoddy" shall be understood to mean all fabrics made wholly or partially of waste hair, mungo, wool extract, waste woollen rags, . . . and all articles in which cotton, linen, hair, or other fabrics, or other substances are used in connection with wool or woollen fibres in the manufacture of any cloth or fabric . . . to be offered for sale as woollens, woollen goods, or fabrics.

SECTION III.—All manufacturers of goods or fabrics made in imitation of woollen goods or fabrics . . . not made wholly of new or unused sheep's wool, shall so mark, label, or tag such goods that they may be readily distinguished from genuine wools . . . such label to be so attached . . . that it cannot be detached except by design, and shall accurately state in plain printed letters and figures the constituent materials of which it is composed or the relative probable percentage of each.

SECTION IV.—All persons who shall make any such adulterated or shoddy fabrics into clothing, garments, or any article whatsoever to be sold as such, shall also firmly attach to every article so made a tag or tab similar to that required of the manufacturer, and showing the same facts.

SECTION VIII.—Any person who shall knowingly sell, trade, or exchange, or offer to sell, trade, or exchange, or expose in his place of business for the purpose of trade, sale, or exchange, any clothing, goods or fabrics known as shoddy, as defined in this Act, which is not labelled, marked or tagged according to the provisions of this Act, shall be guilty of a misdemeanour, and be fined not less than 100 and not more than 1000 dollars.

SECTION IX.—Any person who shall wilfully, recklessly or carelessly mark incorrectly any cloth, goods, fabric, or any article manufactured or in the process of manufacture therefrom, required by this Act to be labelled or marked so as

with freedom of action on the part of the manufacturers, and the decision of the Conference to frame legislation on the lines of our Merchandise Marks Act seems to an Englishman the only reasonable line to pursue. Our law simply secures that no article shall be sold as being something which it is not, or as being the product of one country when it is in reality produced in another.

It is true that the shoddy trade is particularly difficult to inspect with this end in view. In America, for example, the best worsted laps, as well as broken tops and noils, are all included under the generic name of shoddy. None of these materials have ever been completely manufactured in the technical meaning of the term, but they have to be returned to re-opening processes before they are of value for spinning, and hence they are not "unused wool." The clippings from soft, white hosiery which has never been worn, as well as fleecy shawls and ladies' knitted wraps, that have completed their first brief existence, can be reduced to a raw material of high spinning quality and of considerable value. All stockings, jerseys and underclothing go to make a coloured shoddy very little inferior in length, capable of spinning to relatively fine counts. Whilst at the other extreme, tailors' clippings from milled woollen cloths, and old garments made from broadcloth, are reduced to mungo, with fine, smooth fibres so short in length that it must be mixed with new wool or some other ingredient, if it is to spin to anything but extremely thick weft counts for backing.

As we have previously seen, the reason which prompted the to show a large percentage of wool or a smaller percentage of shoddy, or cheaper fibre or material; or in any manner that will, or is calculated to, deceive or mislead the purchaser thereof, shall be guilty of a misdemeanour, and shall be fined not less than 50 and not more than 5000 dollars for each offence.

sheep ranchers of the Western States to demand an Anti-Shoddy Bill was pure self-interest. They thought that if the use of shoddy were prohibited by law their wool would be more in demand, and would advance in price. Their arguments were two. The first was, that a cloth of shoddy made from worn-out clothes might easily transmit infection or disease from one generation of wearers to the next. Secondly, that because shoddy is short it must needs be worthless stuff only capable of producing a cloth so devoid of wearing quality as to be fraudulent. The first argument is the one which doubtless influences a vast number of people, and it is very nearly baseless. Some members of the Congress stated as a fact that all the rags they used were carbonized; that is to say, were soaked in sulphuric acid and then baked to pulverize the cotton. Such treatment must of course destroy all germs. It would be interesting to know how large a proportion of the shoddy which goes into use does in reality go through the acid bath, but this is not ascertainable. On the other hand, it is true the rags are not scoured before they are made into shoddy, but all cloth gets a very thorough scouring and cleansing in at least two finishing processes, and this should remove all traces of possible infection, although there is nothing like the temperature of the baking oven for really destroying microbes.

All facts that can be collected go to show that the chances of infection are practically nil. A leading puller in the Yorkshire heavy woollen district, who sorts at least 8000 lbs. of rags per day (many of them being foreign), has never had a case of infectious disease in the last thirty years amongst his sorters. Now, if those girls, who handle every single piece of *uncleansed* rag, are thus immune, it is clear that the user who buys the finished article after it has been carded, woven,

scoured, dyed and finished has no need to count his chances. Let us for a moment suppose that there had been one case (which there has not) of measles amongst the 100 sorters who have handled 75 million lbs. of rags that the firm have sorted in this term of years. Seventy-five million pounds will make at least 10 million suits of clothes, and if infection were not removed by dyeing and by scouring the chances would be at the absurdly low rate of 1 in 10 millions against infection to the user.

The ranchers' second argument is little more than childish; the very shortest mungo, rightly used, improves the surface of the finest West of England cloth, and every kind of shoddy, if discreetly mixed and used, may find a place in serviceable goods. If people will insist on buying garments at a rate so low that manufacturers cannot afford to put a fair proportion of good wool in along with the shoddy, it is the buyer, and the buyer only, who is to blame. If he will pay for wool there is not the slightest doubt he can have it.

If we discuss the ranchers' root idea regarding shoddy—the theory that every pound of shoddy used displaces so much wool—we find it quite as incorrect as were their arguments; for there is no proof whatever in support of the case. On the other hand, the table already quoted goes to show conclusively that over a course of years from 1860 onwards a steady advance has taken place in the amount of wool used, side by side with a still greater advance in the amount of shoddy imported into this country.

We read in 1859 that the shoddy trade in Batley had early attracted imports of woollen rags from abroad. The figures were only tabulated separately for the first time in 1860, and in that year they amounted to 17 million lbs. against 148 million

lbs. of wool, 30 millions of which was re-exported. It is only since the flocks of Australia were decimated by the great drought of 1895 that the ratio has materially altered. Our imports of wool reached their greatest magnitude in 1895 with a total of 775 million lbs., 404 millions of which were used in this country. In 1905 these figures had fallen to 620 millions and 342 millions respectively, with a comparative increase in the price per pound. This of course gave a great opportunity for the substitution of wool by shoddy, and it will doubtless account for the alteration of the proportion used. As has already been stated, the amount of imported wool which goes into consumption is 342 millions, and the estimated yearly consumption of shoddy is 180 millions without the cotton that is added in large proportions to improve many of the shorter qualities.

Of all the industries in Great Britain it is probable that none is so purely local as is the production of shoddy. There are 906 machines at work in this country, and no less than 881 are to be found in the heavy woollen district, or, in other words, in Batley and its neighbourhood. Of these machines 566 are in the hands of shoddy manufacturers, whilst 329 are returned as running in woollen factories. At one time Batley enjoyed an entire monopoly of her curious trade. The rags of all nations came there to be treated and to be dispersed once more as new cloth to all quarters of the globe. Now it is different. All European nations now treat their own shoddy more or less. We still import a vast amount of rags from various countries, but so far as the figures of employment show, other European nations as well as ours must be grinding up the cast-off clothes of Indians, South Americans and Poles, as well as enormous quantities from their own inhabitants.

TABLE VII.

PERSONS EMPLOYED IN VARIOUS COUNTRIES IN THE WOOLLEN, WORSTED,
AND SHODDY INDUSTRIES, INCLUDING DYEING.

	Date of return.	Totals employed in wool and worsted trades.	Employed in shoddy trade.	Proportion of persons in shoddy trade to total.
England	1901	219,550	4400	Per cent. 2.0
Scotland	"	27,400	102	0.38
Ireland	"	5,450	—	—
United Kingdom .	"	252,400	4502	1.7
Russia	1896	134,895	—	—
Sweden	"	10,586	—	—
Germany	1895	262,260	7390	2.8
France	1896	213,900	—	—
Switzerland	1895	4,367	193	4.4
Belgium	1896	33,139	581	1.7
Holland	1899	7,697	—	—
Italy	1901	79,391	834	1.0
Austria	1900	53,447	—	—
India	1902	2,854	—	—
United States . . .	1900	130,465	2167	1.6

The English Government returns for 1901, not only show the total number of people engaged in the shoddy trade, but classify them according to age and sex. Table VIII. shows that practically no children are employed in the sorting of shoddy, and that comparatively few are at work in woollen mills of any kind. It also shows that in both shoddy and woollen spinning more men than women are employed, and thereby affords an interesting contrast to the worsted spinning trade.

The figures in Table IX. relating to shoddy are very instructive if they are rightly understood. They must not be taken to mean that the proportion of woollen yarn which contains shoddy is $\frac{7}{140}$ of the pure wool woollen yarns made in the West Riding.

For good or for evil it may as well be acknowledged, that Yorkshire does not produce a very large amount of woollen

yarn that contains nothing but previously unused wool. But the figures may be useful to show how very little shoddy is manufactured into yarn without the addition of some better material to help to make it into serviceable cloth.

TABLE VIII.

RETURN OF PERSONS EMPLOYED IN FACTORIES, 1901.

	Children.		Under 18.		Over 18.		Total.
	Males.	Females.	Males.	Females.	Males.	Females.	
Rag sorting and grinding . . .	1	—	122	390	2,218	1,771	4,502
Woollen spinning .	466	227	4,144	3,522	13,787	6,682	28,828
Wool sorting . .	—	—	—	—	—	—	4,065
„ combing . .	—	—	—	—	—	—	13,105
Worsted spinning .	—	—	—	—	—	—	66,130
							116,630
Weaving, dyeing, etc.	—	—	—	—	—	—	135,770

TABLE IX.

SPINDLES RUNNING IN 1904.

	Woollen.		Worsted.	
	Mule.	Fly, cap, or ring.	Mule.	Fly, cap, or ring.
Spinning shoddy, West Riding .	73,418	400	—	—
Spinning shoddy, England and Wales	73,418	400	—	—
Total spindles, West Riding . .	1,401,869	55,202	126,838	2,558,245
Total spindles, England and Wales	1,977,771	73,918	192,707	2,691,711

Table VII. shows the proportion of people employed in the sorting and grinding of rags in various countries compared with the total number of operatives in the Textile trade in each of them. The output per person, on the average, may be taken

as approximately the same in every case, but unfortunately the carding of shoddy by shoddy makers is included in this table. This introduces an element of some uncertainty, for it is only a small proportion of the rag wool which is treated in this way. A very large proportion of it is carded by the spinner, mixed in all kinds of ways, with cotton, other kinds of shoddy, mungo, noils or wool. From Russia, Sweden, France, Holland, Belgium and Austria no separate figures were returned; but allowing for differences of carding returns, it is clear that Germany makes at least as much as we do. The United States figures, which are very complete, also show that they employ 2167 persons to treat 84 million lbs. of raw material, a proportion almost exactly equal to our 4500 persons treating 180 million lbs. of rags. Doubtless we should not find it easy to procure the rags we need if it were not for the prohibitive tariffs in the United States, for since the Dingley Tariff came in force, all importation of rags by that country has had to cease. All that are used in the States are the "domestic" product, whilst we are able to import as many rags as those produced at home.

TABLE X.

		Value in dollars.
Materials used, 1860	. . . . .	227,952
" " 1870	. . . . .	1,098,000
" " 1880	. . . . .	3,366,000
" " 1890	. . . . .	6,003,000
" " 1897—1907 (average per year)	. . . . .	318,000

It is, of course, impossible to give an exhaustive description of all the various kinds of rag wool and their uses. Many are blended together, and many are blended with wool and noils; but the student who is unfamiliar with the trade may gather something of its intricacy by a brief outline of the classification of various sorts in America, on the continent of Europe, and in

England. It will, at least, show him that it is wholly impossible to draw lines, and to say that broken tops, noils, and hard spinning waste may be used, but that soft hosiery, when it is recarded, is unfit for use.

In America the various materials which are included under the generic head of shoddy, for statistical purposes, are widely different in their nature and quality; for a shoddy merchant in that country includes in his wares—

1. Broken pieces of top with unimpaired staple.
2. Best soft drawing laps containing little or no twist.
3. Noils of low quality used for superior blankets.
4. Noils, double combed; often mixed with the best Australian lambs for West of England goods.
5. Spinning and other twisted waste which has been garnetted.
6. Clippings from soft knit goods, superior to many kinds of unused wool.
7. Clippings from all-wool dress goods.
8. Clippings from tailors' cloths.
9. Old Nubias, fascinators, etc.
10. Old dress goods, which have been made up, and again reduced to fibre.
11. Old cloths (gentlemen's).
12. Skirted merino; composed of rags taken out of old cloths—known as merino, because they contain both wool and cotton.

In this list none of the first eight qualities have ever been contaminated by use; they are all bye-products of various processes in the manufacture of clothes, and there is therefore no more reason to destroy the tailors' clippings, than there would be to destroy all the noils that come from a combing machine.

At the same time, as has already been pointed out, No. 10 would produce a material of much higher spinning value than No. 6 or No. 9, and it is only necessary that this product should be cleansed during its process of renaissance, to make it into a desirable material from the user's point of view. Perhaps this cannot be said with equal truth of shoddy which is made from very ancient garments. For example, the clothes discarded by a tramp cannot be expected to be very clean; but they, like other cloths, may at times be turned into serviceable yarn.

Some members of the Washington Commission took it for granted that wool, being matter, was indestructible. This may be true in theory, but it is certainly not the case in practice. In theory, clothes which are themselves made from shoddy may be separated once again into their constituent fibres, and a third time manufactured into cloth; but, in practice, it is found that the fibres in a well-worn suit of clothes are themselves worn. They have lost a good deal of their original size and weight, and are often deprived of their scales. It is probable that few fibres form a constituent part of more than three different cloths, but if they were to do so, it would be necessary to add a considerable quantity of new wool in order to make the fabric serviceable. Although in theory shoddy cloths may themselves be re-manufactured into mungo, and the resulting dust may be added to give weight to other cloths in the milling process, the United States census figures of 1900 show conclusively that this cannot really be the case, for only 57 per cent. of the materials that go into a shoddy mill reappear in a saleable and more valuable form. Of the 79 million lbs. of rags that go to the machines, 36 millions disappear in the form of dust and sinkage of which there is no further record.

TABLE XI.

STATISTICS OF SHODDY MADE AND USED IN 1900 IN THE UNITED STATES
(FROM CENSUS FIGURES).

Materials used.	Price per pound in pence.	Weight in pounds.	Value in dollars.
Wool, foreign	24·8	17,500	8,700
„ domestic	14·6	404,849	118,399
Hair, camel and vicuna, etc. . .	—	2,000	160
„ buffalo, cow, and fur . . .	—	104,000	10,285
Cotton	—	172,652	15,202
Noils, wool	8·17	4,216,428	689,412
„ camel, alpaca	—	11,600	3,600
„ mohair	—	8,000	960
Cotton waste	—	158,000	4,875
Pieces, clippings, and old rags .	2·23	79,623,312	3,558,706
Total and average prices .	2·53	84,718,341	4,291,900
<hr/>			
Products.			
All-wool yarn	20·0	75,000	30,000
Union and merino mixed yarn .	11·7	157,775	37,077
Wool card-rolls	20·0	5,000	2,000
„ noils	6·1	333,713	40,807
„ waste	4·6	1,608,470	148,043
„ shoddy	6·9	39,014,661	5,388,378
„ extract	6·2	4,980,825	620,504
„ flocks	3·1	2,080,758	131,894
Total .		48,256,202	6,398,703
<hr/>			
Oil used	—	444,342	88,843
Soap „	—	64,350	2,396
Acid and dye-stuffs used . . .	—	—	111,095

In very early days, when all wool rags were little more than rubbish, there was no organization in the trade in them. But now we find a highly organized trade system, competent to deal with vast quantities of the “raw material,” consisting of an infinite variety of fabrics which come to us from almost every country in the world. Until about 1830 it was the custom or all manufacturers who used shoddy to fill their relatively small

requirements by buying direct from itinerant rag gatherers, and to sort such material as they purchased into the various colours and qualities that their trade required, but as the trade increased by leaps and bounds, a class of small merchants arose in Batley, who made it their business to supply the manufacturers in such distant localities as Halifax and Huddersfield with the various kinds that they required. These dealers in shoddy began by sorting their own rags, but before very long, demand arose for such an infinite variety of qualities and shades, that their capacity was overtaxed, and yet another grade of middlemen appeared, who made it their business to "rough sort" rags which were to be sorted again before they reached the hands of the shoddy dealers, or the manufacturers who made them into yarn. This means that many rags in these days passed through the hands of—

The itinerant rag gatherers ;

The professional rag dealer, who trades in nothing else, although he is still known in the heavy woollen district as a marine store dealer ;

The rag sorter or shoddy dealer ; and finally,

The manufacturer.

Rags from abroad are imported for the most part by merchants in the heavy woollen district after they have been through the hands of two or more intermediate dealers in the land of their origin. But many of the larger pullers buy direct when it suits them to do so, and they are also open to sell their imports or other purchases of rags unpulled, to other users, or to merchants who are for the moment anxious to increase their stocks. The trade in rags between the larger manufacturing nations is also liable to strange fluctuations. Sometimes Germany buys from France, and at other times

the tide sets in the opposite direction. At one time France may be a large exporter to our heavy woollen district, but on the other hand there may be seasons when our wants are largely supplemented from Germany, if no French rags are to be had. America buys very little, and she sends some rags to us each year.

The course through which two lots of rags may go in moving, say from Austria to a Batley factory, may vary greatly. Some manufacturers often buy direct from continental merchants. But Batley has its auction sales for rags, just as the wool trade has its London sales. Wool may be bought direct from growers in Australia, or through a London broker. The same is true of rags, a second lot of rags from Austria may be consigned, unsold, by Austrian merchants to the "weekly sales," or rather to one of the broking houses who conduct those sales in Dewsbury. The functions of these brokers are identical with those of London wool firms. Their primary duty is to sell by auction for a foreign client to a home consumer or to a merchant, for a small commission.

They may finance the seller, if he wish to hold his stock, and though they are not buyers in the ordinary course, a lot that finds no buyer at a low market price, may at times be taken in by them to their own account. Thus they combine four functions—those of broker, auctioneer, financier, and merchant. They seldom import themselves, but it may well fall out that Austrian merchants will consign their wares to one of the five leading firms who hold the sales, selling it by this means to merchants in the neighbourhood, who in their turn may sell it to the very user who at other times may buy himself direct from Austria.

Merchants, like manufacturers, may import direct and sell

direct to other manufacturers, as well as selling through the brokers at the sales; for merchants and manufacturers alike both patronize the sales. The organizers of the Dewsbury Sales hold them weekly in their own warehouses. The auctioneers are five in number—

Benjamin Eastwood & Nephew.

F. W. Reuss & Co.

H. Cullingworth & Son.

Jos. Eastwood & Co.

Robert Thornton & Sons.

There is one other feature of the trade that needs a few words in passing. Purely commission firms are quite an exception to the general rule. Many large pulling houses will do commission work for others in the trade, and such work may include carbonizing, pulling, and carding. It is usually undertaken when convenient to the two contracting parties, but there are well-known firms with carbonizing plant who never buy or own the material that they treat. There are as well at least two firms who advertise themselves as pulling on commission and as doing nothing else.

The trade is obviously one regarding which no hard-and-fast statements can be made. It is also an axiom of economics that those trades in which there is most vitality are most flexible in the nature of their methods. If this be true, the shoddy trade shows more than usual signs of life, for no rule can be laid down regarding the course of business; still less can anything really definite be said regarding the various lengths and qualities of shoddy manufactured from various types of cloth. He would be an unwise man who risked his reputation by stating definitely the destination of any of the numerous classes of pulled wool.

Whether rags have been bought direct from itinerant rag gatherers, or from the second class of dealers, they are supposed to be rough sorted before they reach the man whose trade it is to do the final sorting, and to "pull" them into various types and shades of shoddy. The first rough sorting is so very imperfectly done that every puller sorts the rags again, to get his shades and qualities to suit his customers; but first he shakes them to extract the dust and looser dirt that they contain.

From first to last rags go through six or even more sorting processes. First, all must be roughly classed in three great groups—

- I. (A) Rags of animal fibre, including wool and silk.
 - (B) Rags of vegetable fibre, including cotton, linen, and hemp, which go to be ground up for the paper trade.
 - (C) Rags of mixed animal and vegetable fibres for carbonization, or treatment with sulphuric acid. This process destroys the cotton so that the resulting extract contains nothing but wool or silk. It then resembles the first division, but is somewhat less valuable because the application of chemicals and heat has a tendency to harden, or at least to roughen, the fibre.
- II. After all vegetable threads have been removed, rags containing silk threads, or silk in any form, are separated from pure wool.
- III. Each of these two classes is divided again into milled and unmilled fabrics, which in their turn go through still more minute subdivision.
- IV. Milled and unmilled rags are often subdivided into clean and dirty sorts.

- V. At least three qualities may be made from the clean milled rags, one fine, one medium, and one coarse, in each of which there may be many shades.
- VI. Unmilled rags undergo even greater subdivision. Those that are milled have no great difference in length and quality of fibre; but unmilled rags contain remnants of flags, of floorcloths, and of blue serge skirts. They contain fine cashmere dresses, poplins, hosiery, gents' worsted cloths, and many other things. Bunting often contains fibres fully 12 inches long, wiry and hard. Cashmeres and poplins are all short, soft Botany. All kinds of intermediate qualities and lengths are present, some twisted hard, some soft, some medium.
- (A) Gents' worsted cloth is known as "worsted" when it has been pulled.
- (B) The finest of the dress goods and good hosiery are called "merino" in the finished state.
- (C) Flag cloth, strong serge, and all the lower-fibred qualities go as a coarser sort to make a mixture "serge" of blended colours, and of quite considerable length; whilst all the ladies' fabrics are sorted into endless shades and diverse qualities as they pass through the two final stages of their sorting once more to become merino.
- (D) Flannels, both black and white, are made of quite short clothing wool, and go to make a class.

No one will be surprised to hear that in America machinery is called in to make the sorting simpler and more rapid, or that similar methods are in use on the Continent. The rags are

taken from the shaker to a lattice feed, which forms a slowly travelling sorting board. The sorters stand beside it, each one picking from its load the type of cloth it is his duty to select. Beside each sorter is another travelling sheet, on to which the various qualities are thrown to be re-sorted to such shades and types as are desired. A system of this kind would naturally tend to great economy of time and labour, but on the other hand it would be unreasonable to expect great accuracy of colour matching from so mechanical a method. It must also be remembered that the use of such expensive plant would not economize either time or money, unless very large lots were being sorted. For this reason it would be of no use in the fancy trade.

The fact is that the nature of the trade demands great powers of adaptability. In England the six or seven consecutive sortings, which have been named, do not necessarily take place in this, or in any other order. Few batches of material pass through them all. It is the duty of the shoddy maker in this country to make his blends of rags in such a way that the resulting mungo, vicuna, merino, or worsted may exactly match any given shade and quality submitted to him. He sells "to shade" as well as to quality, and as his raw material differs from day to day, so the amounts of black, mixed grey or light, that go to make a given shade, may have to differ also from day to day. Not only must the actual sorters be expert, but those who supervise must ever be on the alert. The proportion of workmen who qualify for supervisors is very small indeed, for they must not only see at a glance what is required, but they must have decision to act with promptness and patience to remain continually on the alert. At times it may be necessary to dye some portion of the rags that form the

blend, but often the original colours of the rags give the required shade. Again, when various types and shades of cloth are dyed up in one large vat to some such shade as olive, it is true that they will all be of one colour but of many varying shades. In such a case, if the blend were put promiscuously through the rag grinder the resulting blend of wool would not be uniform from day to day, and no pains must be spared by the attendant and by the manager to see that uniform proportions of the various shades continue to go to the machine. It may even be necessary to dye a special lot of rags a little darker than the average, and add it now and then to keep the whole correct.

It is the general custom to remove all linings, buttonholes and seams that may have cotton in them, but here again no hard rule can be laid down. Such things as buttons, hooks and eyes, and cords that would be certain to damage the machine, must of course always be removed, and such work is known as "trimming"; but otherwise it often happens that old serge skirts and other simple garments go to the machine but little more disintegrated than they were when on the wearer's back. There is no limit to the endless shades and sorts of shoddy that are derived from various kinds of cloth. Thousands will be made in a single factory in the course of a year, and these go forward to be blended both with new wool and noils, with cotton, with card shoddy, and with all kinds of waste before they take the form of yarn again.

No amount of writing could give a clear conception of the details of this extremely intricate trade, but perhaps the best idea can be given by a brief description of the sorting in a single factory.

(1) In the first room, perhaps a dozen sorters are at work

on **French Imperial black**. The cloth is well cut up, and for the most part milled. It may have been in use as dress coats, "as civilian or clergy wear," or even waiters' clothes. The sorting in this case is simple in the extreme; bits that are faded and off shade, and every kind of seams, are taken out; the rest goes forward to be pulled and sold, not merely as mungo but as French Imperial black. Its length, like that of all other material derived from felted fabrics, is short in the extreme. Few of the resulting fibres will exceed 1 inch in length; a vast majority are under $\frac{1}{2}$ inch and some under half of that (see Fig. 11).



FIG. 11.

The price will vary from as low as $3\frac{1}{2}d.$ up to $5\frac{1}{2}d.$ per lb. after it has been carded.

(2) A second larger room is almost filled with women sorting **Mixed London Merino**. It appears to be gathered from every class of society, for every type of dress goods made of worsted, except serge, is present on the boards. The sorters are expert in recognizing the cotton in whatever form, and anything with cotton warp or silk embroidery is promptly rejected. When this is done sorting for colour commences. First, some eight shades are made; black, dark brown, brown, green, dark blue, scarlet, red, and a great pile of light. "Lights" contains cream, white, pink, blue, blue-grey, light drab, light green, as well as fabrics made from black and white. All these are ultimately sorted into separate skeps. Thus fifteen sorts at least, and often many more, come from this widely varying kind.

Supposing the lot when shaken free from dust was worth $5\frac{3}{4}d.$, "seamed," that is rags from which all the seams are sorted out, would fetch $2\frac{1}{2}d.$ more, and "seams" when carbonized perhaps $1\frac{1}{4}d.$ more. Resulting colours when they have been pulled vary according to demand at different times. Scarlet may easily bring $7\frac{1}{2}d.$; browns, greens, and blacks $1\frac{1}{4}d.$ less; blue about $6d.$ The yarns from such material will be used in many trades, the length of most of it being fairly good; that is to say, a large proportion of the cloths yielding fibres up to quite an inch in length, with many fibres long enough to comb; the very shortest type of fibres being scarce. The average length may be perhaps $\frac{3}{4}$ inch, but as the devils deliver on to the pile everything that comes to them, it is natural that many fibres under $\frac{1}{2}$ inch in length are also present.

(3) **Dutch flannels**, which have been already carbonized and dyed, are treated as a class. The carbonizing has destroyed both cotton warp and cotton seams if there were any. The sorting is "to shade." Badly dyed pieces, known as contrary colours, rags that have silk in them, and all the coarsest bits are taken out. The rest, when carefully mixed to ensure a regular blend, will all go forward to be pulled, and very likely carded.

Flannels, of course, give very widely varying types of shoddy; they are made in the first place from shorter types of clothing wool, if not from lambs', the average length of staple being short, certainly under two inches. The milling they have gone through is not so severe as to bind the fibres very tightly to one another, but in the pulling process the nature of the weft and the twist in different threads is sure to cause much breakage, and hence the rag wool that results is very short, though very soft and close. As it comes from the devil, both bits of thread and ragged bits of cloth are to

be seen, but on the whole the opening process is wonderfully complete. A few odd fibres may be found over an inch in length, but for the most part they are a great deal less, and the diagram, as far as it is possible to construct one, shows a great preponderance of the shorter fibres. A novice in the trade would naturally suppose that this extreme shortness would affect the price, but length is not a desideratum in this trade; quality, softness, and felting power are of more importance, and for this reason this short, but very fine, material sells in the grey for $10\frac{1}{2}d.$ per lb., if the colour is good enough to allow of its being dyed to light shades of blue or pink, or other delicate colours (see Fig. 11).

The lower class of flannel, carbonized and then dyed, gives rather better length, but as the quality is far inferior it only brings $5\frac{1}{2}d.$ per lb. when dyed.

(4) **Ladies' blue Serges**, which of course form a large class, arrive fairly well sorted at the factory. Here again sorting is for colour, and for nothing else. In one particular lot, the seams are taken out, all bits of black that have escaped in previous sortings are now rejected, the rest goes to four piles: extra dark navy, standard navy, and light go separately to be pulled, and reappear as various shades of navy serge; the faded, which is sorted as a separate class, has to be dyed again before it can be blended with the rest.

(5) A curious class of sorting is that seen in **English black Merinos**; they, like the previous lot, arrive well sorted so far as colour and quality are concerned, but seams and buttonholes are often to be seen. All the best pieces that are free from seams or any kind of cotton are taken out to form a class called "seamed." Parts that consist of seams and little else clipped off in previous sortings form the lowest grade, but in

between them comes the "partly seamed," a nondescript collection not good enough to have the cotton taken out; too good to carbonize along with the short grey. The wool resulting when these sorts are pulled is fairly good in length, the fibres varying from 1 inch to $\frac{1}{4}$ inch. It really is a mungo, but with a wise discrimination, the trade prefers to buy and sell such wool as black merino at prices varying from 4*d.* to 6*d.*

(6) **New tailors' clippings** are an easy and a cleanly class to sort. They are divided into Cheviot, Worsted, Fine Mixed Grey, and Light. They have no seams in them. The length of the fine mixed grey and of the light grey cloth, like that



FIG. 12.

of many other kinds of material pulled from felted cloths, is naturally shorter than the fibre from unmilled rags, and it may vary from 1 inch to less than $\frac{1}{4}$ inch. The cheviot and the worsted yield much longer stapled material, like that in Fig. 12.

(7) The seams from similar qualities of cloth, as well as those taken from No. 5, are carbonized and mixed with other unseamed cloth for men's wear, going to make a grey worsted. The length, of course, is apt to vary; some of the fibres measure one inch long, as in the previous lot, but as this quality is not quite free from cotton ends, the price may not be more than 4*d.* per lb.

(8) One other quality is worth more than passing notice;

it is a **Fine red-grey Merino**, extremely similar to No. 2, but blended with some super-clothing wool. This, adding greatly to the average length, gives it good spinning power without reducing the softness, and the diagram it makes shows much more fibre at the longer end. This increase in the average length gives it a greater value than any of the other shoddies previously mentioned. It sells at 13*d*. (see Fig. 13).

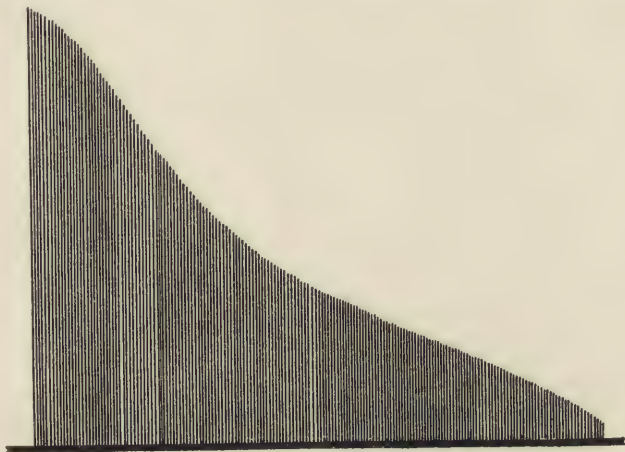


FIG. 13.

(9) The last sort that it is necessary to describe is a **coarse grey Serge**. The pile which is ready for the devil is an uninviting-looking heap. Remnants of well-worn flags, horse cloths, and various coloured rags that have been used for floor-cloths, or other menial work. The quality is low, but the length of fibre good, the bunting, for example, being made of good long English wool. It is difficult to believe that any one process can reduce such strong and well-made fabrics to a state in which every integral fibre is detached from its next-door neighbour. True, minute portions of unopened yarn, and even little bits of fabric, often escape the action of the teeth,

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financial results from any lot of rags. It is another case of individual judgment in the man who has to sell the finished article, and it ought to show to the student and to the beginner that there are few trades in which the introduction of brains will give a better return.

An intricate and very mobile trade is always one that leaves a margin to the man who understands its details thoroughly and who knows how to take advantage of every variation in the numerous processes. But, on the other hand, it is just this kind of trade that causes disappointment to the man who follows it without due intelligence, or without the method to apply the knowledge that he may possess. It is a trade where high cylinder speed does not necessarily mean great output, with consequent low cost of production; yet it is a trade where low cost of production is essential; where every detail that goes to make up its total must be thoroughly understood by those who wish to prosper.

The man who understands his costing thoroughly has many things to carry in his head. He must know, first of all, the cost of every process, quite apart from the cost of sinkage. For example, if a card will produce 1000 lbs. a week, and cost in wages and oversight 20s., he must not conclude that $\frac{240 \times 2}{1000}$ represents the amount that he must charge to a commission customer. For certain kinds of work $\frac{1}{2}d.$ a lb. may pay; but cards need so much floor space, engine room, and steam for heating, that the ratio of wages to the total cost of production is very different in different cases. The output and class of work performed on cards of equal size with different qualities will also vary, and consequently the cost per lb. will seldom be the same for long together.

In theory, the simplest way to cost would be to divide the

total output of a factory, for a given time, by the total cost for the same period in rent, rates, taxes, depreciation, power, sundries, and wages. This is practically the method adopted in the combing trade, where every lot of material treated, goes through identically the same process. With rags it is far otherwise. A complete factory comprises at least six processes — shaking, carbonizing, dyeing, sorting, pulling, carding; whereas comparatively few lots go through the entire course. Many lots are only shaken, sorted, and then pulled. Others, besides these processes, are dyed and then re-sorted to some special shade, prior to being pulled. Some will be carbonized instead of being dyed, whilst sorts like faded black merino, which is taken as an example in costing, not only go through the whole six processes, but get an extra sorting to ensure correctness in shade. It will be obvious to the least technical reader that under these circumstances the costing must always involve no small amount of calculation. The manufacturer must know exactly what is the cost of each of his processes calculated on a commission basis. Further, he must know the amount of loss that a lot will suffer in every one of them. It is not sufficient that he should know the total weight of raw material and that of the carded shoddy. A net loss of weight plus the total cost of commission work would give a wrong result. Based on such a method the figures would be—

Commission Carbonizing	1 $\frac{1}{4}$ d.
„ Dyeing	$\frac{3}{4}$
„ Sorting out silk	$\frac{1}{4}$
„ Pulling	$\frac{1}{4}$
„ Carding	$\frac{3}{4}$
	<hr/>
	3 $\frac{1}{4}$ d.

The sinkage mounts up to 30 per cent. Therefore—

10 lbs. of shaken rags at $4\frac{3}{4}d.$ = $47\frac{1}{2}d.$

7 lbs. of carded shoddy at $6\frac{3}{4}d.$ = $47\frac{1}{4}d.$

+ Cost of commission work $3\frac{1}{4}$

+ Oil $\frac{1}{4}$

$10\frac{1}{4}d.$

This gives a result that is $1\frac{1}{4}d.$ more than the actual cost which is shown in Table XII. It is printed not because the figures bear any relation to the actual cost, but to show the method that will give the most accurate results.

This discrepancy occurs because—

First, of the addition of oil.

Second, because the cost of carding and pulling are charged on the total weight of rag wool, although in reality only 8 lbs., or less, was done by each of these two processes.

TABLE XII.

METHOD OF COSTING A CARBONIZED CARDED DYED BLACK MERINO.

	per lb.
Cost of faded black merino rags at 42s. per cwt. gross = $4\frac{1}{2}d.$ = 42s.	
The bag and all dirt are paid for net, therefore the net rags will be, say, 107 lbs. and after discounting cost . . .	$4\frac{3}{4}d.$ = 42s.
Carbonizing, say	10 lbs. at $4\frac{3}{4}d.$ = $47\frac{1}{2}d.$
Cost of carbonizing in acid, steam, wages, etc.	„ „ $\frac{1}{4}d.$ = $2\frac{1}{2}d.$
Carbonized material resulting	8 lbs. at $6\frac{1}{4}d.$ = 50 d.
Cost of dyeing (room-power, dyeware, etc.)	$\frac{3}{4}d.$
„ shaking and sorting out silk . . .	$\frac{1}{4}d.$
„ rags ready for pulling	<u>$7\frac{1}{4}d.$</u>
„ pulling (room-power, wages, etc., say 5s. 6d. per pack with oil found) . . .	$\frac{1}{8}d.$
Weighed to carding	10 lbs. at $7\frac{1}{8}d.$ = $73\frac{3}{4}d.$
Charge for „	9 „ $\frac{3}{4}d.$ = $6\frac{3}{4}d.$
Cost of carded dyed black merino	9 „ 9 d. = <u>$80\frac{1}{2}d.$</u>

This intricate calculation is obviously incomplete. There is nothing to show how the various costs of dyeing, carbonizing, and pulling are obtained. As a matter of fact, each must be the result of a calculation based on a number of data. To ascertain exactly how much carbonizing costs, the manufacturer must know the total cost of his carbonizing department in rent, rates and taxes, steam and acid, wages, etc.; and in the dyeing a series of similar figures are necessary, with dyeware to take the place of acid.

Even the cost of sorting is not as simple as it looks, for though it is usually paid for by the piece, the rates of piece work vary with various lots. The rent of the warehouse must also be included, and as the relation of output to wages is not always alike, the relation of rent to wages must vary as well. The costing of pulling, which is merely stated at $\frac{1}{8}d.$ per lb., is also complicated. If we reckon that each "devil" will do twenty packs per week, this figure must be divided into the total cost of room, power, depreciation, and wages, to find the commission cost per pack, which may roughly be divided as under:—

	£	s.	d.
Rent, rates, taxes, gas, etc.	10	0	
Power	2	0	0
Depreciation, very heavy owing to the short life of the swift	12	6	
Wages and oversight	2	12	6
	<hr/>		
21 packs at 5s. 6d.	5	14	6

But 5s. 6d. is more than $\frac{1}{4}d.$ per lb. and is not the real cost of the process on the resulting shoddy. Although sinkage takes place in other processes, no sinkage takes place here, for every

pound of rags that goes into the machine finds its way into the bin, and as about 36 lbs. of oil are added to each pack of rags, together with a little hot distilled water, the weight of shoddy is 20 lbs. per pack more than that of the rags from which it is made. The cost of the process is therefore relatively low. The enormous energy exerted by the pegs of the swift in beating the cloth into its component fibres generates so much heat that all the water is evaporated, and a portion of the oil is apparently used up as lubricant; for the following figures may be taken as a fair illustration of the case in point.

The amount of water added is of great importance. A certain quantity is a necessity. Too much will give worse results. Dyed goods require more than those undyed, and it must never be forgotten that a little hot water is much better than a lot of cold, because the former penetrates both cloth and yarn in a much shorter time.

Cost of a lot—

240 lbs. of rag at $7\frac{1}{2}d.$	1800 <i>d.</i>
36 lbs. of oil (9 gallons) at $2d.$	72
Cost of power and wages	66
	<hr/>
	1938 <i>d.</i>

Result, 263 lbs. of shoddy at $7\frac{3}{8}d.$ = 1939*d.*, showing a cost of only $\frac{1}{8}d.$ per lb. for pulling, as stated in Table XII.

All these figures must be regarded only as approximate. They are not given for any intrinsic value that they possess, but to show the method of costing in use in some of the leading firms in the trade.

CHAPTER V

OILS AND SOAPS

IF the question of cost could be left out of account, the following chapter might be condensed into a very small space, for olive oil is universally admitted to be the best lubricant for wool, and olive oil soap the best material for washing it. Unfortunately, in all textile trades the question of cost is very important indeed, and in the woollen trade, in particular, the percentage of oil applied, prior to carding, is so great that the use of expensive oils is out of the question in nearly every instance. Olive oil is still used by spinners, who make pure wool yarns of fine counts; and the spinning value of olive oil should never be lost sight of by those who desire the finest possible thread from any given batch of wool. Many substitutes for olive oil are used in the woollen trade. Of these it is hard to say which is the most generally used, but undoubtedly oleine is one of the commonest substitutes.

The demand for oils at ridiculously low prices tends to a vast amount of adulteration, and, in consequence, drying oils, such as linseed, and particularly semi-drying oils, like rape and cotton oil, are freely used for blending. All these oils are constituted very largely of saponifiable acids; that is to say, they are easy to wash out of yarn or cloth, because they combine with caustic alkalis to form soap. The same

cannot be said of the mineral hydrocarbon oil, which is also used in large quantities, in mixtures that are sold as "pulling oil."

Unlike vegetable oils and oleine, the mineral oils consist very largely of unsaponifiable matter. They are, therefore, less easy to remove prior to dyeing, but if blended with oleic acid in the proportion of 8 to 1, they will form a complete emulsion with one part of a half per cent. solution of soda. This means that they can be washed out of cloth or yarn if right methods are applied. In addition to these types of lubricants, emulsions of olive oil, or other vegetable oils and oleines, are often prepared with aqueous solutions of ammonia or sodium carbonate. Put into other words, this means that oil or oleic acid is turned into an emulsion or milky mixture with water, by means of soap solution.

Oils which are to be used for the lubrication of wool should be as free as possible from mineral oil—

First, because the best oils are those most easy to remove; but

Second, because the "flash point" of mineral oils is almost always lower than that of vegetable oils.

The flash point of an oil is equivalent to the temperature at which it will ignite without a wick, and it is therefore of the utmost importance to a user to know—

First, the amount of unsaponifiable matter; and

Second, the flash point of the oil that he is using.

In 1895 the Fire Insurance Companies charged additional premiums to users of various types of oil according to the schedule given below.

Oils for which there is no extra charge are, olive oil, lard oil, and oleine. These contain less than 10 per cent. unsaponifiable matter, with a flash point not under 340° F.

A higher premium is charged for oils containing between 30-50 per cent. of unsaponifiable matter.

A little higher rate for "recovered oil" otherwise equal to the above.

The highest rate of all for "manufactured" oils with over 50 per cent. of unsaponifiable matter, for mineral oil, and for many of the drying or half-drying oils.

This makes it quite clear that if the user wants good value for his insurance premiums, he must use good oil, and if he deliberately chooses to use lubricant of very inferior quality, he must be content to lose something in security, or in actual cash out of pocket.

This scale is doubtless arranged to agree with the flash points of mineral oils, for it is fair to conclude that the amount of mineral increases in proportion to the amount of unsaponifiable matter. There is one other point that is worthy of mention. The drying oils are not only liable to form a varnish-like film on the wool fibres that they are used to lubricate, but they may easily generate sufficient heat by oxidation to cause spontaneous combustion. This does not only apply to the blending or teasing room, where the oil is applied; for oil is also present in such quantities in the card room, that if it be sufficiently inflammable, a minimum of heat may be the cause of a conflagration. The danger is greater with large piles of oily wool, and is not lessened by the presence of some moisture.

Lewkowitsch divides oils derived from organic sources into four large classes.

1. **Liquid Waxes**, which occur solely in marine animals, and consist chiefly of compound ethers of fatty acids and monovalent alcohols. For this reason a large percentage of their constituent

parts is unsaponifiable. They absorb very little oxygen, or in other words, they do not dry.

2. **Fish oils** and **Blubber oils** are liquid glycerides. They absorb large quantities of oxygen, but **they do not dry into hard varnishes**, though they thicken and become sticky.

3. **Drying oils** consist for the most part of glycerides of linolic and linolenic acids. They also absorb large quantities of oxygen, and in so doing, they **dry into varnishes** on exposure in thin layers to air.

Non-drying oils contain large quantities of olein, but **do not dry** or stiffen on exposure to the atmosphere.

CLASS I.—Of these there are only two true representatives known as yet. They are **sperm** and **Arctic sperm oil**. They are readily distinguished from all other fixed oils by yielding a large proportion of unsaponifiable matter. Most other oils yield 95 per cent. of fat acids on saponification, whilst they contain only 60–65 per cent.; the remaining 35–40 per cent. being largely monovalent alcohols, usually crystalline solids, and quite different from the unsaponifiable mineral oils.

They are also easy to distinguish, because their S.G. is very low, only about 0.875 at 15° C. (60° F.), and because their viscosity is less influenced by temperature than is that of other oils. They are, however, frequently adulterated with mineral oils which are also of low gravity.

CLASS 2.—**The marine animal oils** are easily distinguishable by their fishy smell and taste. They are distinguished from land animal oils because, like drying oils, they absorb oxygen rapidly, although they **do not dry** to a firm varnish. Land animal oils, on the other hand, are non-drying oils, and absorb very little oxygen.

Liver oils from certain fish, especially of the shark tribe,

contain considerable quantities of unsaponifiable matter like sperm, but combined with other easily oxidizable fats.

The S.G. of these oils varies but little, from 0.915 to 0.930, and their chemical constitution is yet but imperfectly understood. They may be subdivided into three classes—

(a) **Fish oil**, such as American Menhaden oil prepared from the head and intestines of fish (S.G. 0.927).

(b) **Liver oils**, such as cod-liver, obtained from pressing the putrefied livers of the fish after which they are called. Cod-liver oil has a S.G. of 0.922 to 0.930, and is frequently adulterated with mineral and resin oils, non-drying oils, and drying oils, such as cotton seed.

(c) **Blubber oils**, such as seal oil, whale oil, porpoise oil, etc. (S.G. from 0.915 to 0.927), are much less oxidizable than the true fish oils, though more so than those of land animals.

ANIMAL OILS, as the term is usually understood, are those derived from the feet of oxen, horses, sheep, etc., and from fats by pressing.

Neatsfoot is the oil obtained from the feet of oxen by boiling in water. It is odourless and of pale yellow colour, with a S.G. of 0.914 to 0.916. The genuine article is rare, because sheep and horses' feet are frequently used along with those of oxen. It is a satisfactory lubricant because it is slow to turn rancid; but its high price per ton offers great temptation to adulteration with fish, seed, and mineral oils. These mixtures can, however, be easily detected by chemical methods.

The VEGETABLE OILS, or liquid fats, may be divided, as already stated, into three groups—

DRYING OILS, comprising amongst many others, linseed, hemp seed, walnut oil, and poppy oil, are wholly unsuitable for the lubricating of wool, for the simple reason that they

form a varnish-like film on any fibre to which they are applied.

They are therefore of little interest to a textile worker, and no pains should be spared to see that they are not used to adulterate other oil used for the lubrication of wool.

Linseed oil, which may be taken as typical of this class, is, however, often used as stock material for soft soaps, on account of its cheapness, but it finds its greater value in the manufacture of boiled oils for paints or varnishes. When pressed cold it is golden yellow in colour, but if extracted at a higher temperature it takes a browner hue. It is the heaviest of this class of fatty oils, reaching a S.G. of 0.937 at 15° C. It may be adulterated with other drying and non-drying oils, but as it is very cheap this is not often the case. Admixture with it of resin, mineral and fish oils, is, however, often practised.

None of these adulterants can be more injurious to spinning value than is the oil itself, and they therefore concern us but little. The three other drying oils already mentioned have many things in common with linseed oil.

Hemp seed has also a high S.G. (0.927), and is used for paints and for making soft soap, which has a dark green colour. Walnut oil (S.G. 0.926) is often used in the production of artists' colours, for it is almost colourless and dries into a varnish that is not liable to crack.

Poppy seed oil has also a S.G. of about 0.926. It is one of the best drying oils, and is used considerably for ordinary purposes, but is of greatest interest to the textile trade as a common adulterant of olive oil.

SEMI-DRYING OILS are often subdivided into three groups—

(a) **Cotton seed** group, containing cotton seed oil, sesamé oil, etc.

(b) **Rape seed** group, containing rape or colza oil and many other little-known oils.

(c) **Castor oil** group.

Of the **cotton seed** group, cotton seed oil itself is by far the most important member. Its name is sufficient indication of its origin. As it is pressed from the seed it varies from red to almost black in colour, but after purification (often by saponification) it is pale to golden yellow (S.G. 0.922), and the finest brands intended for edible purposes are freed from stearine. It is largely used in the production of soap, but it is also employed in immense quantities in the adulteration of olive oil, lard, butter fat, and in the production of butter substitutes. Its drying power corresponds to its high iodine value, and it may be regarded as typical of semi-drying oils. Its detection when mixed with these materials is an important branch of fat analysis. Its drying power may be estimated from the fact that in one day it will absorb 5.9 per cent. of its weight of oxygen. Linseed oil absorbs 14.3 per cent., whereas sesamé oil only absorbs 2.4 per cent. in seven days. It is this drying tendency that makes cotton oil so injurious to the spinning value of wool.

The Rape Seed and Colza group oils are derived from seeds of the Cruciferae. They are noticeable for the fact that they have a lower saponification value than other vegetable oils. So few of them are known in the textile world that it is only necessary to say a few words regarding rape or colza oil, which is the most important member of the class to which it gives its name. In this country the terms "rape" and "colza" are used indiscriminately, but on the Continent they are applied to two slightly different classes of oil. The S.G. of rape oil varies from 0.912 to 0.915 at 15° C. The unsaponifiable

matter is only about 1 per cent., but the percentage of free fatty acids is apt to vary from $\frac{1}{2}$ per cent. to figures as high as 6 or $6\frac{1}{2}$ per cent. Its drying value is not high, as it only absorbs 2.9 per cent. of its weight of oxygen in seven days; but, nevertheless, it is unsuitable for the lubrication of wool. It is best known as a burning oil, and like most other oils it is liable to adulteration with other cheaper seed oils and fish oils, as well as paraffin and resin oils.

Castor oil may be said to form a class to itself. It is pressed from the seeds of *Ricinus communis*. It is transparent, colourless, or pale green, and is distinguished from all other oil by its very high viscosity, few other oils approaching it in this respect. It has also the highest S.G. (0.969) of any natural fatty oil.

Adulteration is easily detected, but its high price induces people to mix rape, resin, and other oils with it, particularly after they have been thickened by blowing. It is largely used in medicine, and also in the production of soap, and the manufacture of Turkey red oil.

NON-DRYING OILS.—There is a long list of oils belonging to this class, but most of them are very little known. Almond oil and six others are from the seeds or stones of fruit trees, and several are the produce of nuts, but by far the most important of the first class is the olive oil, which is pressed from the fruit of the olive tree.

Olive oil of commerce contains very many different qualities, which nevertheless may all be unadulterated. In the first place there are a very large number of varieties of the olive fruit itself, and in addition the quality of the oil is affected by the ripeness of the fruit, the way it is gathered, and the way in which the oil is pressed from the fruit. The finest hand-picked

fruit is used for the manufacture of the best edible oils. An inferior quality is also used for salads, and for application to wool, by the most particular worsted manufacturers.

The next grade is used for soap-making and burning. The lowest grades of pressed oils are also used for soap. They are obtained by grinding up the remnants of the fruit (which have already been pressed twice or more) with ground kernels of the olive, mixing them with a small quantity of water and pressing once again. Even below this, there is a quality which is obtained from the pressed residue, with solvents like carbon bisulphide or petroleum ether. But as these contain a proportion of free fatty acids as high as 26 per cent. they are wholly unsuitable for wool, and are only suitable for the production of soap or emulsions (as in the manufacture of Turkey red oil). Olive oil is supposed to contain about 72 per cent. of practically pure olein, the remainder being mostly the solid fat, palmitin. The small amount of unsaponifiable matter (under 2 per cent.) makes it especially valuable for application to wool and in the production of high quality soft soaps. But samples containing more than 5 per cent. free acid are dangerous as lubricants for wool, and those containing over 10 per cent. should be rejected, because they are apt to act on the steel of card clothing or the pins of fallers. The acid pits the metal and makes it too rough to do good work. Because of its relatively high price, olive oil is enormously adulterated, especially with cotton seed and other drying oils. These ruin its value as a wool lubricant, and it is most important to all users to have their olive oil tested before use, lest the material to which it is applied should be injured rather than improved by its addition.

The various methods of detecting adulteration involve

chemistry of an order which is too purely scientific to be discussed in this book, but it is worth while to mention that olive oil has the smallest refractive power of any vegetable oil. Serious adulteration can be detected by any one who learns to use the refractometer, a simple optical instrument which may be obtained from Zeiss & Co., of Jena, or from their agents.

TABLE XIII.

OLIVERI'S REFRACTOMETER DEVIATIONS.

	Deviation in graduations.		Deviation in graduations.
Olive oil	0.2	Colza oil	26.5
Cotton seed oil	18	Poppy seed oil	28.5
Sesamé oil	15.5	Castor oil	41.4

OLEINE or OLEIC ACID¹ is very largely used for the lubrication of wool, and in the manufacture of soaps. A large proportion of the olein on the market is a by-product, resulting from the manufacture of candles. The fats chiefly used are tallow and palm oil. Often they are mixed, but there is nothing to prevent their being used separately. The commercial products are obtained by various processes.

When the fats are saponifiable by means of lime and decomposed by sulphuric acid, the resulting oleine or red oil is technically known as saponified oleine. If acid saponification is adopted, the fatty acids are collected and purified by distillation, and the resulting oil is referred to as distilled oleine. The fats in use in the candle trade are also saponified by water under a pressure of 220 to 270 lbs. and distillation in a current of superheated steam. Where sulphuric acid is employed in the process the resulting oleine is liable to contain

¹ The true olein of the chemist is the neutral fat, glycerin oleate, contained in olive oil. Commercial oleins are mostly oleic acid, as stated. If distilled they invariably contain unsaponifiable oils resembling mineral oils, but actually arising from chemical changes in the oleic acid.

free acid when it comes to the market, and as free acid will attack the wire of carding engines, the pins of combs and porcupines, the user should be sure of his ground before employing the cheap oleines for use on wool in his machinery. If the card clothing is roughened or pitted by the acid, this costly portion of the manufacturer's outfit will require renewing much sooner than ought to be the case, and will produce less perfect work for a great part of its existence. The acid or crude oleine as it comes from the press, will also act injuriously upon the fibre of the wool itself.

The "**red oil**" is dark brown in colour, and turbid, but when it is purified to the condition of pale oleine it is transparent, varying in colour from yellow to light brown. Such oleines are particularly suitable for soap manufacturers, and because they contain little except saponifiable fats, any free acid will naturally be neutralized in the process of soap-making.

Oleine is also obtained from wool fat, cotton-seed oil, foots, and wood oils; but these materials may contain large quantities of unsaponifiable matter, and are therefore less suitable for use in the wool industry. Even high-class oleine supplied for this purpose is apt to contain the acids of linseed oil which has been mixed with the tallow stearine for purely technical purposes.

RECOVERED OILS AND FATS, which are by-products of the wool and other industries, are largely used in the pulling of rags and in other departments of the woollen trade in combination with other oils. The principal kinds may be said to be—

1. Wool fat or "recovered brown grease."
2. Distilled grease.

3. Cotton-seed oil foots.
4. Fuller's grease or seed oil.
5. Black oil.
6. Wool oils and cloth oils.

Wool fat or **suint** is the natural grease which is removed from sheep's wool in the washing process. In this country the dirty liquor or suds are collected in tanks, acidified, usually with sulphuric acid, and left to stand until the magma or separated greasy matter rises to the surface in the form of a dense scum or cake, which is removed, filtered, and pressed at a high temperature. The resulting brown grease is nearly solid, with a strong and peculiar smell; its S.G. is very high, 0.973, almost equal to that of water. It melts at 39-42° C. When this heavy grease is distilled a light hydrocarbon oil is first to come away, the heavier fats coming over together after further heating. These are separated into a solid and a liquid portion, each of which is treated exactly as in the case in candle-making, the final products being an oleine which is largely used as wool oil and a stearine suitable for leather dressing, soap or inferior candles.

Lanoline is also prepared from brown grease. It consists of about 80 per cent. of pure wool fat and about 20 per cent. of water. It is a very soft ointment, extremely suitable for the preparation of salves. If gently heated the water separates from the fatty matter, which is peculiar in combining again with water if the two are kneaded together. The stearine and oleine obtained from cotton-oil foots are recovered in ways which so strongly resemble those employed in candle and wool fat industries that they are put to very similar uses.

Fuller's grease is the name given to the spent liquors that come from the scouring of silk, woollen, and cotton goods.

In this case the quality of the grease recovered depends very largely on the kind of soap employed in scouring. Where only the best olive-oil soap has been used the resulting grease will consist almost entirely of pure fatty acids which can be directly made into soap. Suds from low union goods, on the other hand, may contain mineral oil and other hydrocarbons, as well as dirt, from which they must be separated by distillation. Oleine from this process is generally used as wool oil.

Black recovered oil is extracted by pressure from the greasy waste of woollen mills, and it always strongly resembles the oil that was applied to the wool before it was worked. It may therefore contain anything from olive oil, in a scale descending through various types of oleine, to the very lowest quality of hydrocarbon or mineral oils.

Mineral Oils, such as are exclusively used in the preparation of the lowest cloth oils and brown pulling oil, are derived from crude petroleum, or distilled from oil-bearing shale. The hydrocarbon oils that are derived from petroleum are frequently dis-

TABLE XIV.

	Specific gravity at 17.5° C.	Flash point at ° C.
Russian cylinder oil . . .	0.911-0.923	183-238
" machine " . . .	0.893-0.920	138-198
" spindle " . . .	0.893-0.895	163-167
American cylinder oil . . .	0.886-0.889	280-283
" machine " . . .	0.884-0.920	187-206
" spindle " . . .	0.908-0.911	187-200
Rape oil, crude . . .	0.920	265
" refined . . .	0.911	305
Olive oil . . .	0.914	305
Castor " . . .	0.963	275
Linseed oil . . .	0.930	285
Tallow . . .	0.951	265

tilled, though it is also possible to refine them by treatment with animal char. Their great advantage is their cheapness and

their viscosity at high temperature, but the fact should never be lost sight of that they are not saponifiable, and that many of them give off inflammable gases at relatively low temperatures. The lowest temperature at which this occurs is called the flash point, and it is determined by heating the oil gently in the presence of a small flame. As soon as gas is evolved there will be a slight explosion or flash upon the surface of the oil. It is, of course, obvious that if friction in work should accidentally raise any oil above this temperature a conflagration is very likely to occur. The thickest hydrocarbon oils (*i.e.* those with the greatest viscosity, at high temperature) have the highest flash point, and are therefore the safest to use, but only the very best American cylinder oils are equal to crude rape oil and tallow in this respect; whereas many spindle oils have a flash point little more than half that of olive oil.

Table XIV. shows more plainly than any amount of writing, the reason that olive oil is preferred by insurance companies

TABLE XV.

	Flash point.	Saponifiable matter.	Unsaponifiable matter.
	° C.	Per cent.	Per cent.
1. Brown oleine distilled from foreign oil	396	86.28	12.95
2. " " from Belgium	354	80.56	18.69
3. " "oleine cloth oil," "manu- factured"	349	73.78	25.58
4. Black oil recovered from flannels lubricated with No. 1	367	69.08	29.65
5. Brown grease recovered after using olive oil	419	69.16	29.77
6. Distilled oleine from No. 5	342	62.04	37.19
7. Black oil recovered after using oleine and better class oil	369	60.39	38.50
8. Brown oleine distilled from No. 5	338	46.96	52.35
9. Black oil recovered after using low cloth oil	331	32.03	67.30
10. Brown pulling oil (for rags), brown grease, and hydrocarbons	374	21.01	78.25

to any other lubricant. In the first place, it keeps down the temperature in various processes by means of its excellent lubricating properties, and even were the temperature to rise, it must reach a heat that is more than three times that of boiling water before inflammable gases are produced.

Olive oil is the best lubricant for wool, but unfortunately its price is almost prohibitive for anything but the highest class of woollen goods, and the following table from Lewkowitsch will give some idea of the extraordinary diversity of oils that are used for pulling, carding, and spinning woollen yarns.

SOAP.—All that it is necessary to say about this abstruse subject may be summed up for our purpose in a very few words. In chemical language soaps are alkaline salts of fatty acids. Lime and many other metallic bases form soaps with various fats, but in commerce it is only fats in combination with caustic soda and caustic potash that are included in the term. All commercial soaps have the unique property of lathering freely in water, and as acting as good detergents, or, in simpler English, cleansers. Potash soaps are those which we call soft, whereas soda soaps are hard. Tallow, palm oil, cotton seed oil, and cocoa-nut oil, are most often used for hard soap; and olive, cotton seed, and linseed oils are the chief ingredients of soft soaps. Olive oil is undoubtedly the best possible material for textile soaps, and it is particularly worthy of notice that third or fourth quality oil will produce first quality soap. It has the great advantage that it remains liquid in very concentrated solutions, and is therefore able to insinuate itself between the wool fibre and the dirt on its surface, as well as within the substance of the fibres themselves.

Cotton seed soap is used very largely in place of olive soap, and still more extensively as an adulterant. Because it is a

drying oil, it is, however, apt to oxidize and go rancid with the production of yellow stains in the finished soap.

Linseed is very largely used in making domestic soft soap, but for exactly similar reasons it cannot be too carefully excluded from the washing of wool and woollen fabrics.

Oleine soaps are seldom offered as such on the market, although oleine, consisting almost wholly of free saponifiable fatty acids is very easy to convert into soap. The process is so easy that caustic alkali is unnecessary, for oleine will unite with sodium carbonate if they are boiled together.

It will be noticed that only such greases as have a high percentage of saponifiable fats are used for soap making, and that all mineral oils and liquid waxes are rigorously excluded. Dr. Lewkowitsch also classes recovered grease as an adulterant, although it is now used in large quantities for textile purposes after distillation.

Resin in soap should be used with the utmost caution, for it may lead to very unpleasant results in milling, and all kinds of filling like flour or silicate of soda should be rigorously excluded. Under no circumstance should soap for the washing of wool contain any free caustic alkali. Any one can try the experiment of dissolving large quantities of wool in solutions of caustic soda or caustic potash. It is a very speedy process if the solution is strong, and even if relatively weak the epidermis will be entirely removed from fibres in two or three minutes. Such weak solutions as may occur in washing bowls will easily roughen the scales. Therefore if an alkaline solution is required, the washer is most strongly recommended to buy his soap neutral, and add a carbonate of potash or soda that he knows to be free from caustic.

On the other hand there should be no unsaponified or

unsaponifiable fat present. Such material may settle on the fibre or fabric and cause stains in dyeing.

From the spinners' point of view there is not the slightest doubt that high quality soft soaps pay well. The finisher may be less particular. For fine goods, most people regard high-class olive soap as being worth its cost; but when it is a question of scouring low-class woollens that contain up to 18 per cent. wool oils, with high percentage of hydrocarbons, something drastic must be done to emulsify and remove these unsaponifiable lubricants.

It is clear that no hard-and-fast line can be laid down in regard to the relative utility and cost of inferior qualities of soap. The best soap will do the best work. It is a question for manufacturers to decide whether cheapness is so essential that they dare sacrifice some efficiency to secure it.

CHAPTER VI

OPENING PROCESSES

IF a student who is not personally acquainted with the woollen trade should happen to take up a book on the subject, he is not unlikely to be misled by the number of opening processes that are described in detail. If a writer decides to describe all the opening processes in use in various trades, he is almost certain to convey to his readers an undue idea of the importance of these machines. It is true that each machine forms a process to itself, but most of the opening and shaking machines are so simple in their action and have such an enormous output, that only one of each kind is necessary to supply the wants of eight or ten sets of cards.

A great many machines of this class are also relatively small in size; and they need but little floor space, as compared with a single carding engine. Most of them have no expensive clothing, and they do not therefore form an important item in the cost of equipping a factory. Most of them also have the great advantage that they involve very little expense in upkeep. The cost of the work they do would therefore be so small as to be almost negligible, if it were not for the fact that many of them run very fast indeed, and absorb a relatively large amount of power.

To illustrate their true position it will be well to make a list of the machinery in an imaginary factory producing nothing but

pure wool yarns—that is, yarns that are free from shoddy or any other type of pulled material. In such a factory with an output of fifty packs per week there would be—

	sq. yds.
(1st) 1 willey to open the wool for a set of	9
(2nd) 3 large washing bowls; output as above stated	
(3rd) 1 drying machine, say, 32 feet by 12 feet by 9½ feet high	44
or if the wool in use is very short	
(4th) 1 self-acting teaser 9 feet by 9 feet, or 1 single fan willey 9 feet by 9 feet	9
(5th) 8 sets of scribbling machines, consisting of one 2-swift scribbler and one 2-swift carder, each card occupying 10 feet by 50 feet, or a total of	440
(6th) 8 pairs of mules, say, 400 spindles, 3-inch pitch 100 feet long each, total area needed, say	600
(7th) 2 pirn winders, 200 spindles each	30
(8th) 2 drum winders, 80 spindles each	30
(9th) Warping machines, output varying very greatly with plain or fancy work	30
Besides a large amount of room for storing, mixing, etc., say	400

In addition to the above many factories also contain complete carbonizing plants, including—

4 acid steeping tanks, each 5 feet by 5 feet and 5 feet deep, say	16
1 hydro-extractor 66 inches diameter	4
1 drying machine 32 feet by 12 feet	44
1 burr crushing machine 9 feet by 10 feet	10

	sq. yds.
2 washing or neutralizing tanks	6
1 teaser or willey	4
together with a room for stacking, mixing, and feeding wool to the machines, which would equal	220
requiring in all a room at least 20 yards by 10 yards or	300

The machinery requisite for dealing with mixtures of wool with shoddy, or wool and shoddy with mungo and cotton, necessarily vary very greatly in different branches of the trade, because the machines always vary in their output according to the nature of the work they are doing. The number and size of the machines would therefore differ in each case. Moreover, different factories do not always employ the same processes for the same class of materials. It is, therefore, very difficult to make any statement that will convey to a student a correct idea of the relative importance of the different machines.

Generalization is always dangerous ; but it is fairly safe to say that the blending of diverse classes of materials is far commoner in the woollen than in the worsted trade. In the latter, if more than one kind of wool is to go to form a lot, the length and quantities of the components are always kept as much alike as possible. For example, if a maker is desirous of producing a 60^s top, he may mix scoured or fleece-washed colonial wool with a similar quality of greasy fleece; but for no possible purpose would he dream of adding a crossbred wool of twice the length to the blend. In woollen, on the contrary, mungo which averages half an inch or less in length is often blended with lambs' wool, which will be about 2 inches long, or with 1 $\frac{3}{8}$ -inch cotton, before they are carded together. It

is by no means easy to make such materials blend thoroughly throughout an entire lot, and the methods that are adopted in mixing them are consequently much more complicated than anything that is comparable with this process in the worsted trade.

In order to avoid confusion, and at the risk of some little repetition, these opening processes will be treated separately for the two different sections of the woollen trade.

Those which are used for the treatment of pure wool will be taken first.

Those in use for blending wool with cotton, or wool with shoddy, will be taken second.

And, lastly, those for opening rags and for the production of other "pulled products."

Machinery for the Treatment of Pure Wool.—Some years ago there was a considerable difference of opinion as to the value of willeying wool prior to washing. Some people contended that any opening process increased the tendency of the wool to felt in the washing bowls. This may have been true in the days when wool was propelled by sticks through the bowls, which had no mechanical means of doing the washing; but modern washing machinery gives, if anything, too little work to the wool in its journey through the suds, and the willey, in some form or other, is now in almost universal use, in both the worsted and the woollen trades. The use of the willey is another instance of the fact that money may be saved by spending money on additional processes; for if heavy, greasy wool, or felted scoured, goes straight to the plunger of a washing bowl, it may be forced under water and travel a long way through the sud before the soap and hot water are able to act on all the fibres that it contains. It is also certain that willeying not

only opens the wool, so that the sud acts more easily upon all portions of it, but it also removes a considerable quantity of the sand or other dry impurities that such wool contains. This is especially true of all wools that have been removed from skins by the use of lime or other reagents. As explained elsewhere, lime will destroy a very large amount of soap ; and therefore all wool which contains lime, in the form of tiny lumps, or even as dust, should have the lime removed before it reaches the sud. There is, moreover, less objection to the use of the toothed willey in the woollen trade than in the worsted trade.

In the first place, the staple is usually much shorter, and there is therefore less tendency to break the fibre. Very long wools, such as are used for crossbred worsted yarn, would come under the action of so many pins at one time that some fibres would certainly be injured, and their spinning power thereby reduced, whereas the shorter staples of a "carding quality" will only be separated from one another in the process. But, on the other hand, the woollen spinner should never lose sight of the fact that in fine yarns, the longer the staple the less the twist required to obtain a given strength ; and where carded yarns are used for hosiery, those with less twist will necessarily be of greater relative value, because a given weight will produce a more bulky fabric.

The first object of a willey should be to loosen the solid matter in heavy, sandy, or limed wools ; and the second object to open the staples of the wool itself. Machines that will effect this end without causing the breakage of any fibres are those of the greatest value to the user ; but he must also remember that the very different classes of wool, which are used in different sections of the woollen trade, will naturally require different types of machinery, or machines very differently adjusted.

The **best colonial greasy fleece**, such as is used for super West of England yarns and cloth, needs very little opening between the sorting and the washing bowl. Many firms put it straight into the suds ; but, as has been already explained, less heat and weaker reagents are necessary to remove the impurities from thoroughly opened wool, and a willey of some form will certainly increase the efficiency, if not the output, of washing machinery. The longest types of wool which are used in the West of England are quite long enough to be combed, and methods resembling those in modern combing plants are therefore applicable.

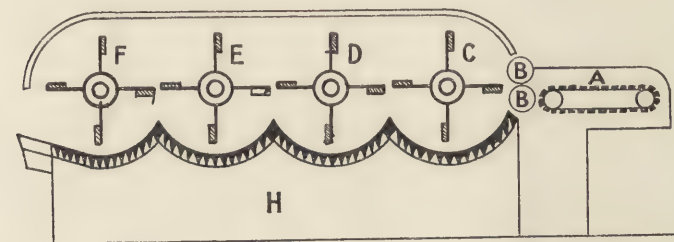


FIG. 15.

For such a trade, a willey with four fans is now in use (see Fig. 15), which has no teeth or pegs. The wool is fed on to a lattice feed sheet A, and travels to the feed rollers B, B, which are about 4 inches in diameter. The lower one is driven ; the upper, being of considerable weight, acts without other pressure. The four wings of the first fan C revolve close past the nip, beating the staples as they emerge from the rollers and rushing each away as soon as it is free. The grid below the fans allows the dust and heavy sand to fall away into the chamber H. The grid is shaped so that the wool is carried round until it meets the downward coming beater of the second fan marked D. The shock is of necessity very violent ; but, on the other hand, the

wool is absolutely free, not being held by means of any kind. It therefore parts with sand or dust or lime, and hurries forward to receive exactly similar treatment from the fans E and F, before it is ejected with considerable impetus at the further end of the machine.

Each fan should run a little faster than the one before it to prevent the accumulation of wool in the machine. If this is the case, no rolling or felting is likely to occur.

Scoured Wools, if they are treated by themselves, may need severer handling. The washing which they receive in the Colonies before they are packed, gives them a certain tendency to felt; in fact, the large majority of scoured lots have lost their fleece-like character so completely that individual staples are far from easy to find. The original arrangement of fibre on the back of the sheep is greatly altered. Fibres of various staples are often so much interlaced with one another that some of them are almost certain to break before the carding process is completed, whether they are willeyed or not. If they are willeyed they will wash and card more easily; the card clothing will have less wear and tear, and if the willey used is suitable, the carded fibres should be no more injured than if they were carded only.

The 4-fan willey shown on page 130 may well be altered slightly for this type of wool. The feed sheet A (see Fig. 16), and the feed rollers B, B may be identical, but a toothed swift C will give better results if used in the place of the first two fans. Its teeth will have more power to separate fibres of one staple from others with which they are intertwined, and if it be not set too near to the nip of the feed rollers, it should have very little tendency to injure the staple. The distance between the nip of the rollers to the tip of the pins should be adjustable,

for the pins enable the swift to pull the wool to pieces and hurry it in smaller quantities towards the beater D, which acts exactly like the fans of Fig. 15, shaking the sand and dust away so that they fall down through the grid into the dust chamber H. In some machines the dust chamber is fitted with a fan that acts as an exhaust. This arrangement has one disadvantage. Fibres that have been entirely separated from their fellows by the action of the swift may very easily be sucked away and lost.

Mixtures of scoured wool with greasy fleece, which are very often made, may very suitably be treated on the same machine

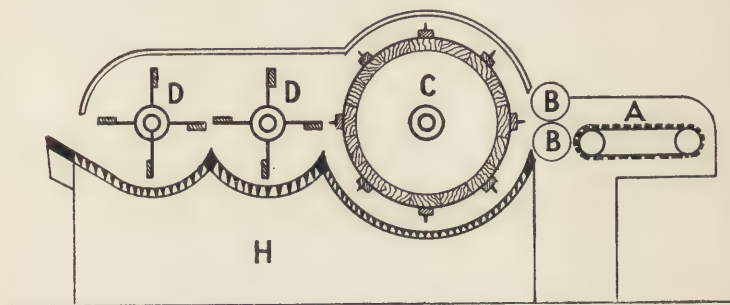


FIG. 16.

But if greasy or good staple is used the feed rollers may be set back a little more than in the case of scoured. If it is a case of mixing greasy lambs with shorter scoured wool no damage need be done, however near the swift be set to the type of feed rollers already described, and it may be generally admitted that swifts with teeth are more efficient, for blending, than any arrangement of simple fans.

Cheviot Wools.—Where such are used for carded yarns in the tweed district, opinions differ widely as to the value of different processes. Some people even advocate the breakage of the longest fibres for certain types of yarn. Others preserve

the length with special care, knowing that greater length of fibre means possibility of longer draft with consequent advantage both in result and output. Clearly, if matted wool were put into a teaser, it would break before it opened, and teasers that are used for longer wool must be adjusted to suit each special lot. If it is desired to preserve the length, the pins should be shorter and fewer in number, so that there will be little chance of any fibre being held by two of them at once. The user may take it for granted that wool of whatever length will be slightly shortened in the process, and it is for him to consider whether the saving that he will effect in the washing and the lightness of the washed wool, will repay him for this reduction in length.

Slipes, whenever they are used, should invariably be willeyed. The process should remove so much lime in the form of dust or lumps that the cost of soap in washing would be very greatly reduced. One pound of lime will destroy about fifteen pounds of potash soap, and as the resulting compound (which is known as lime soap) is disastrous to after-processes, there is no question of the advantage of a shaking process in this case. It is true that a shaking process like that employed for cleaning dirty rags (see Fig. 23) would be better than nothing for a purpose of this kind; but a machine with feed-rollers has the great advantage that it crushes the lime to powder, and for this purpose the spiral vane willey would be as good as anything that could be designed (see Fig. 10). The writer's experience of beaters with arms or rods has led to the conclusion that they tend to roll, and therefore tangle long wool, and it is for this reason that machines with continuous feed and continuous delivery have a distinct advantage, particularly if the total amount of wool contained in the machine at a given time is relatively small.

There is one point in regard to all these machines that deserves particular mention. Critics say that any machine from which wool is continually ejected by fast-running fans is not perfect as a blender. In theory the reason is easy to see. If scoured and greasy are going through together, both are thrown out at an equal pace; but it is contended that the heavier greasy will travel further than the lighter scoured. This means that the side of the pile furthest from the machine will contain an undue proportion of the heaviest material. In many years' practice the writer has never seen anything of this defect, for it is seldom that the bin into which the wool is thrown is large enough to allow the types of wool to separate. Both strike the farther side of the bin, and fall in a well-mixed pile upon the floor.

In further confirmation of this view, it may be stated that, in a factory where opened spinning waste was being blended in a similar manner with new-washed wool, the mixing was particularly well done. The waste was dark steel-grey, the wool was white. The opportunity for seeing if the blend was uniform throughout was therefore very good, and not the smallest sign of irregular blending was visible, in spite of the fact that there was nothing to limit the distance to which the material might be thrown. Apparently the longer wool and the shorter waste travelled equally well in practice, whatever they should do in theory.

One other point in the principle of construction in these machines deserves more than passing notice. A swift with pegs on its periphery may be made in four different ways. It may consist of a turned-up cylinder of wood, on which the different rows of pegs are fixed (see Fig. 17). This method minimizes the amount of draught caused by the revolution,

and makes the opening depend entirely on the action of the pegs or pins, as in the rag machine. It is a type seldom or never used for opening wool.

The second and most usual type of all is one that combines the action of the fan with that of pegs or teeth. The cylinder is some few inches smaller than the one in Fig. 17. This cylinder is lagged at intervals with strips of wood, say 2 inches by 2 inches in section, and on their outer edges stand the pegs. These pegs (see Fig. 17*a*) are largely responsible for the opening action that takes place, but the lags or beaters create

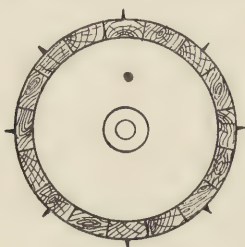
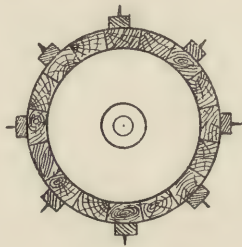


FIG. 17.

FIG. 17*a*.

sufficient draught to carry the wool forward, and keep it all the while in contact with the grids.

A third type has no cylinder at all. The pegs are riveted to simple strips of metal, supported by the discs that keep them in their place. The wool is free to fly within the track of the teeth, as in the spiral vane willey. This type of machines is therefore nearly always equipped with an exhaust fan (see Fig. 17*b*).

The fourth type is in simple fact a fan with teeth upon its edges, and it is very seldom used. In it the circumference of the swift is wholly absent, but every arm is plated from one end to the other. The draught set up by such a swift (see Fig. 17*c*) is very great indeed. It is so strong that wool that

is not firmly held in place will be carried away by the rush of air before the teeth can act upon it, and consequently, if the fan is used at all, the pegs are nearly always omitted, as in the case of Fig. 15.

Machinery for blending Wool with Cotton or Shoddy.—On the continent of Europe it appears to be the usual practice to put the materials which are to be spun through several opening processes, each of which is specially designed to do more work than the one preceding it. Amongst the many types of willeys which are in use, there is one that does little more than beat the wool with flail-like arms.

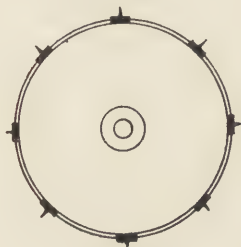


FIG. 17b.



FIG. 17c.

A set of opening machinery often begins with one of these beaters, and at times it is followed by a second machine of similar construction, having three sets of overlapping beating arms. It is obvious that such a machine would shake the wool very vigorously, and it would certainly be unable to break any of the individual fibres. Wool coming from it would therefore be free enough to go through the drastic treatment which the teaser always gives, without being materially shortened in staple.

This type of opening process is, however, seldom employed in this country, though a similar machine, shown in Fig. 17*d*, is

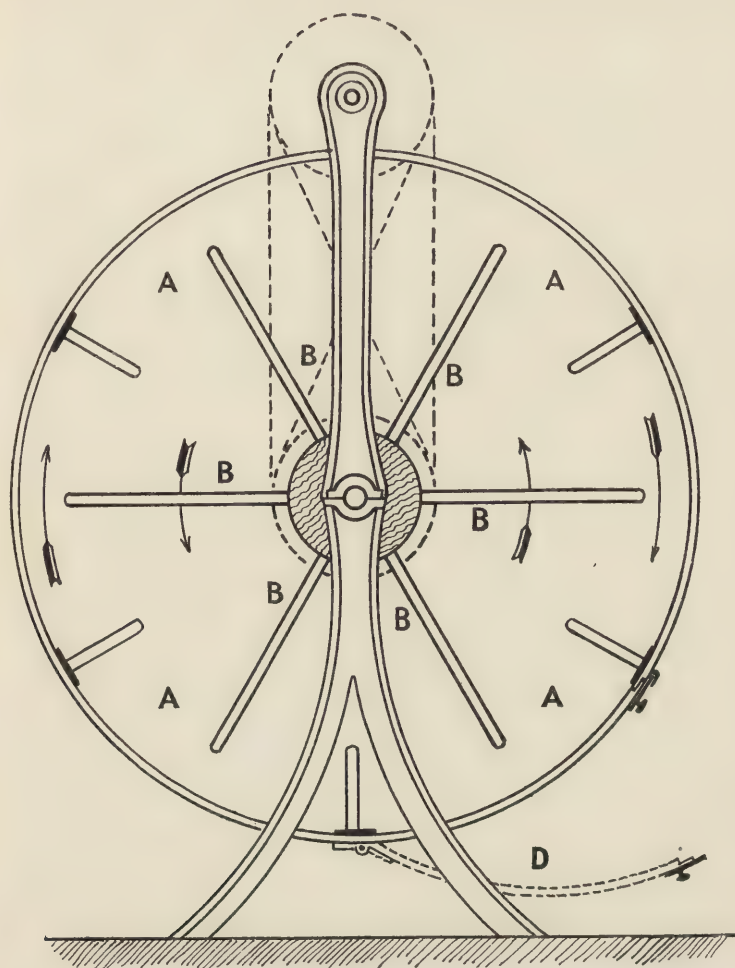


FIG. 17d.—SHAKING MACHINE.

AA. Cylinder of wire lattice, 60 in. \times 60 in., carrying pegs as shown; revolving 6 or more revolutions per minute in the direction of the outer arrows.

B, B. Arms revolving in the opposite direction at the same speed.

D. Door by which charges are put in and taken out. Shown in the position for emptying the machine.

When the machine is started, the movement of the cylinder and the pegs A, A, carries the material against the arms B, B, by which it is violently beaten. Dust falls through the wire on to the floor.

very often seen in a certain class of factories, and does very effective work as a shaker.

The first opening and blending are nearly always done in the **self-acting teaser**; and it is safe to say that few factories

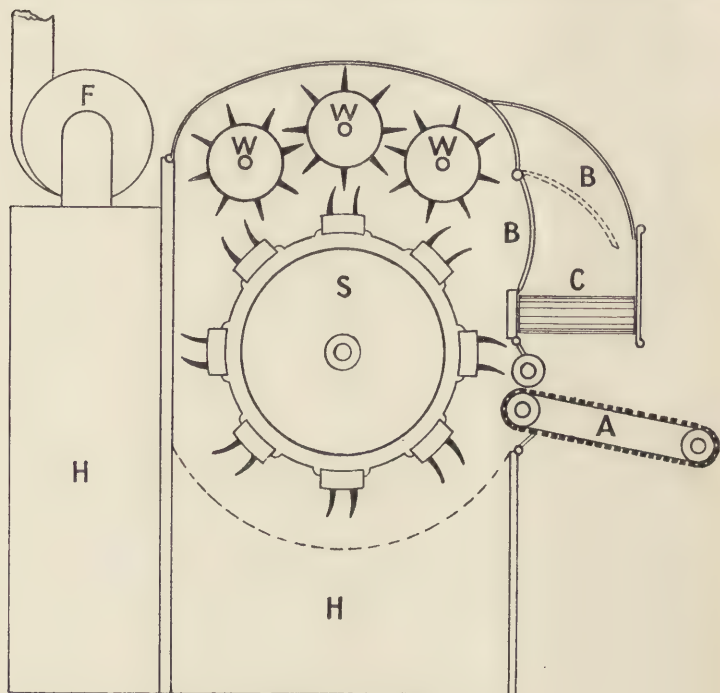


FIG. 18.—TEAZER.

- A. Intermittent lattice feed.
- B. Door through which the wool is discharged on to.
- C. Lattice feed which carries away the material.
- S. 36-in. swift, with 3-in. teeth; 500 revolutions per minute.
- W. 8-in. workers with 3-in. teeth; 30 revolutions per minute.
- H, H. Hoppers into which dust falls through the grid.
- F. Exhaust fan arranged to draw away the dust.

that deal with pulled wool products in any shape, can be found without one of these machines. As far as can be gathered, their principles of construction have altered very little in the last thirty years. There is also a curious uniformity of our

methods and those in use on the continent, in regard to the type of swift, and in the number and size of workers employed. The swift, with its eight or ten double rows of teeth, must be familiar to every reader of textile books, and it is obvious that the long strong teeth of the three workers that revolve above it are set so far into the teeth of the swift that no lock of wool can escape from their clutches without being roughly handled (see Fig. 18).

The action of the machine is so severe that nothing like it is employed in the worsted trade, where all breakages of fibre must be avoided at all costs. It is clear that any lock of wool that is long enough to be caught by any two teeth on the same wing of the swift, at the same time, will be liable to be cut in two when it is rushed against the teeth of the workers, which work into one another as well as into the swift itself.

Five hundred revolutions per minute of a 36-inch swift give a speed of 45 miles per hour, or 792 inches per second, and as every lock of wool is dashed many times against the workers with this velocity, it is obvious that the staple must suffer if the adjustment is not absolutely correct. For example, the teeth of the worker should always pass exactly halfway between any two teeth on the swift, and if by any accident or wear of collars, the rollers come to have any lateral play, they will alter in their relative positions until the teeth are nearer to one another on one side than on the other, leaving a gap on the opposite side. Under such conditions the work will not be satisfactory.

The teaser is essentially a machine for short materials, and is seldom found in factories where only pure wool is used. The swift is usually about 36 inches in width on the teeth, each

arm carrying two rows of pins, which are $2\frac{1}{2}$ or 3 inches long when the teaser is new, standing 2 or 3 inches from one another. At the point of contact the 8-inch workers travel in the same direction as the swift, at a speed from 20 to 30 revolutions per minute, or a surface velocity of 12 inches per second, so that there is a difference of 780 inches per second in the surface speed of the two. This means that in every minute that the wool remains in the machine, 96,000 swift-pegs pass between the teeth of the workers, and the effect on any class of materials must therefore be very severe. The swift and the workers are all enclosed in a dust-tight case. Until a few years ago the machine was fed by hand. It was also emptied by hand, when the operator thought that the wool had been sufficiently worked. This method is now obsolete, and the machine is quite automatic. The mixture of materials to be treated is fed on to a lattice apron, A, which carries it intermittently to the machine, where it remains within reach of the teeth of the swift until the door B opens automatically and the material is discharged by a second lattice sheet, C, at a height sufficient to throw it direct on to a pile or into a bag.

The length of time which the material remains in the machine may be altered as desired by altering the change-wheel which controls the opening and shutting of the door B. There is, therefore, no risk such as there was in the older machines; which was due to the taking out of the wool by hand, whilst the swift was in motion.

Fear-naught.—On the continent and in some English woollen mills the work of the teaser is supplemented by the use of a "Fear-naught," which is really a very coarsely clothed carding-machine. Like the teaser, it has a swift and several

workers, but the nature of their teeth and their positions in regard to one another are different.

The Fear-naught probably derives its name from the nature of its teeth, which are not only more numerous than those of the teaser, but are curved in a way that is probably suggestive of the "set" of card clothing. It differs, also, because its action is continuous and not intermittent. The

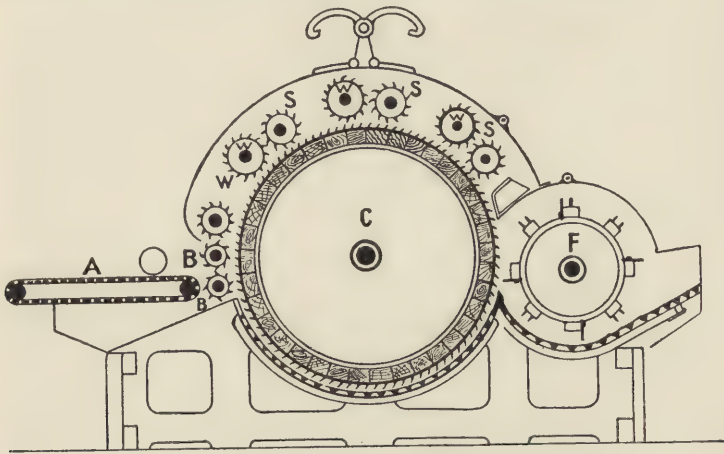


FIG. 19.—FEAR-NAUGHT, OR TENTERHOOK WILLEY.

A. Lattice feed sheet.			
B. 4-in. feed rollers.	12	revolutions per minute.	
C. 36-in swift.	160-240	"	"
D. 6-in. workers.	10-12	"	"
S. 5-in. strippers.	550-700	"	"
F. 18-in. fan or blearer.	760-960	"	"

wool or other blend of material is placed upon the feed-sheet, A, by hand, and is carried to the swift by the feed-rollers, B. The swift, C, in its turn carries it past the teeth of the workers, W, round which a portion of it travels. In this way the various locks of wool are separated from one another and have their fibres opened, before they are finally removed from the swift by the action of the brush-covered roller or fan, F, which takes the place of a doffer in a carding-machine.

It is true that scoured wool or other fleecy material which goes through a teaser would be separated into individual locks ; but there are many instances of blends in the woollen process that have to be so perfectly mixed that the blending must be well advanced before they reach the scribbler. Mr. Marshall laid great emphasis on the necessity of thorough blending prior to carding, and men who hold the same opinions as he did will be most likely to use a Fear-naught as well as a teaser.

It is well that every one should remember the great difference there is in the number of processes employed respectively, in the worsted and woollen trades, between washing and weaving. Worsted material goes through at least sixteen processes in order to blend it and make it regular in size, quality, and weight. In woollen, if the Fear-naught is left out, there are only four—teazing, carding, condensing, and spinning. In none of these are there any doubling processes that are comparable to the seventy-two which are obtained in a Noble comb ; and it is all the more necessary that the blend of material which goes to the scribbler should be more perfectly mixed than in the case of worsted material. The reason is very simple. If unevenness or irregularity occur in woollen carding, there is little if any chance of their being remedied in subsequent processes.

For this reason the Fear-naught is particularly applicable to those sections of the trade that blend numerous classes of material prior to carding ; and it may be said to be essential for blends of material that differ widely from one another in length or quality. It is obvious that blending can never really be efficient until the various locks of wool, laps of cotton, or lumps of mungo are separated into different fibres. The teeth of the teaser are too coarse to effect this end. They may

separate the wool into locks, and mix the locks with no small uniformity throughout a pile, but it remains for the Fear-naught (or tenter-hook willey) to separate fibre from fibre and blend the individual hairs of one class of material with individual hairs of other kinds. This is necessary, because the character of mungo is so dissimilar from that of unused wool that there would be a great tendency for certain rollers of a card to collect one class of material whilst longer or coarser material was collected and treated by such rollers as were set and clothed with finer or coarser wire, as the case might be.

Almost everything that is said of the principles which apply to carding may be applied to this machine, if the action of the doffer is excepted. For the swift is really a carrying roller, which bears the wool from the feed rollers past the points of the pins on the workers (not between them). If a lock of wool is held by a large proportion of its length in the teeth of the swift, the ends of the fibres that protrude will be hurried past the teeth of the workers, and will be combed by all the workers in succession before it reaches the doffing roller, and is brushed out into the pile behind the machine. If this were the usual course of action, only one end of every staple would be carded or combed, and locks would still retain their original character, but it is clear from results that much more than this is effected, and we may assume without fear of contradiction that the swift does not as a rule hold the locks at all tightly after snatching them from the feed rollers B, B. As each lock emerges slowly from the feed rollers, which revolve only 144 per minute or $2\frac{1}{2}$ inches per second, the leading end will be thoroughly combed by the passing teeth of the swift, so that when the lock is finally released by the feed rollers, this combed portion will be caught

by the swift. The uncombed end will remain above the points of the pins in such a way that this portion will be thrown against the pins of the worker, and there held, because the more numerous pins of the slow-moving worker will take firm hold of the uncombed portion and retain their hold, in spite of the combing action of the swift on their opposite ends of the lock.

This action is due to the fact that the points of the pins on the swift C (Fig. 20) are inclined in the direction in which they travel, and also because they meet the pins of the worker W point to point. The speed of the rollers is so far different that whichever way the worker revolves, the action is almost the same. If the swift makes 160 revolutions per minute or 324 inches per second, and the worker 10 revolutions or 2 inches per second, the teeth of the one will pass the teeth of the other at a speed of $324 + 2$ inches per second if the worker revolves against the swift, and $324 - 2$ inches if it

retreats before it. In principle, therefore, the direction of rotation of the workers is of little moment, for in either case the wool will remain in the teeth until they are cleared by the action of the stripper.

The relation of the teeth of the worker W and stripper S is exactly the opposite of that of the worker and the swift. Instead of meeting point to point, both incline in the

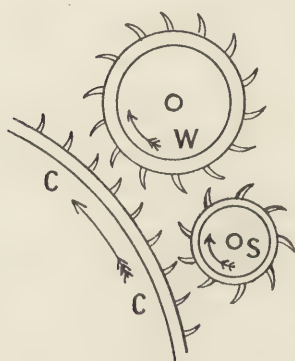


FIG. 20.

same direction (Fig. 20), and as the teeth of the stripper are moving much faster than those of the worker, they naturally rake all the wool from its surface and carry it away. To us

the interest of the operation lies in the fact that the stripper gets hold of the combed end of the tuft and leaves the uncombed portion outside its pins, in such a position that when the tuft comes within reach of the swift it is the uncombed portion that is now held by its pins. This action is made easy because the pins of the swift and of the stripper are both inclined in the same direction at their point of contact, exactly as in the case of worker and the stripper. The swift in this case overruns the worker by 160 inches per minute. The result is that the position of the wool has been reversed by the action of the first worker and the first stripper, so that the next pair may complete the process by combing the uncombed end. When completely combed, the fibres will of course have less inclination to adhere to one another, and as they are separated at subsequent working points, they will blend the more readily with separate fibres of other materials.

The roller which takes the place of the doffer of a card acts in a manner so entirely different that no fancy is required to raise the wool in the teeth of the swift. Whereas a doffer runs much more slowly than the swift it clears, the case is reversed in the Fear-naught. The roller F, which is covered with alternate rows of teeth and leather strips, acts like a fan or brush, and whisks away the material from the swift into the bin or box placed ready to receive it.

The pulling of rags may fairly be regarded as a special branch of the woollen trade, whether it is found in a fully equipped factory or existing as a separate business. But, on the other hand, it is by no means uncommon to find in woollen spinning mills, machines that are used for the sole purpose of treating the hard spinning waste, or other by-products

in such a way as to make it possible to use the material over again, instead of selling it as waste.

Untwisted waste from the condenser may, of course, be returned to the feed sheet of the card without any intermediate treatment, but hard or twisted waste would do injury to the clothing if it were fed unopened into fine carding engines. A Garnett machine is, therefore, frequently employed to prepare the hard waste for the carding machine proper (see Fig. 21).

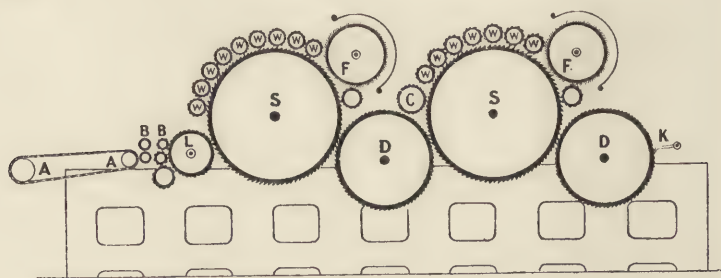


FIG. 21.—GARNETT MACHINE.

- | | |
|--|-----------------------------|
| A. Feed sheet. | B. Feed rollers. |
| L. Lickerin. | S. 36-in. or 40-in. swifts. |
| W, W. 6-in workers acting against the swift without strippers. | |
| F, F. 12-in fancys, covered with ordinary clothing. | |
| D, D. 24-in doffers. | K. Doffing knife. |

Garnett machines are really carding engines, clothed not with wire set in flexible vulcanized foundations, but with hard steel teeth resembling endless thin saw-blades, A or B, which are set in spiral grooves cut in the iron rollers of the card (see Fig. 22). Their action is, of course, severer than the action of a card, because of the rigidity of their teeth. They effectually pull to pieces any yarn submitted to their action. This is not to say that no traces of yarn could be found in the material after treatment in a "Garnett," but such small pieces of material as do escape thorough opening

are small enough to do but little injury to the card clothing. Or, if some special lot of hard material had to be treated, it might be put twice through the machine.

It will be obvious to every one that if two rollers of unequal size are covered with spiral clothing it is quite impossible for the teeth of the workers or other rollers to work into the spaces in the swift, as is the case in the teaser and sometimes in the Fear-naught. Garnetting is a near approach to carding proper, although the only rollers

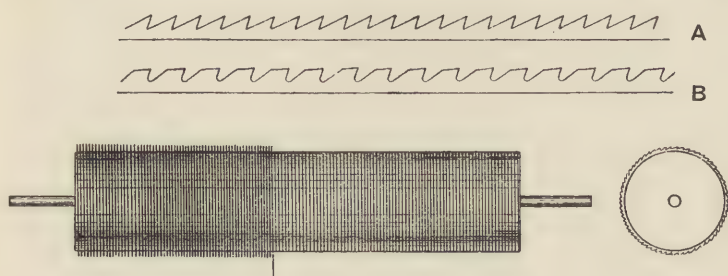


FIG. 22.

that have flexible clothing are the fancies. Garnett wire has the great advantage that it is very slow to lose its points, but there is the corresponding disadvantage that when the point is once lost the clothing is to all intents and purposes useless, and must be replaced at considerable expense. Rollers to be reclothed must be returned to the maker; and for this reason it is an accepted fact that the prevention of accidents is cheaper than their cure.

Nevertheless, accidents will happen, and they are chiefly due to carelessness in collecting and sorting the waste that they are to treat. That which is taken from the floor is liable to contain bits of wire or other hard material. Not only will such substances damage the Garnett clothing in

less time than it takes to write the words, but the friction they produce is apt to generate sufficient heat to ignite inflammable materials such as cotton, and hence the danger of fire must be strictly guarded against.

For sound, clean wool of good staple, such as is used for the best West of England woollens, only one simple opening process should be necessary, and where it is desirable to maintain the greatest possible length of staple, the single fan or one-toothed swift willey should be sufficient.

With sandy or dusty wool this may be supplemented or replaced by a teaser, because that machine, as already described, has a fan which removes the dust into a separate chamber (see Fig. 18). The other machines already described are really designed for mixing, rather than for simply opening various materials, and if they are installed to deal with shoddy and mungo, amongst other things, it must be clearly understood that their function is to mix the pulled material, not to take any part in separating cloth or yarn into their constituent fibres. These processes require special machinery which is designed to do the work efficiently, in the order described in the chapter on Shoddy.

Machinery for Shaking and Pulling Rags.—The purpose of the **rag-shaker** or duster is entirely different to that of any machine hitherto described, if we except the machine of which an illustration is given on page 137.

Rags are put through this machine, not to open them or mix them, but to beat and shake them in such a way that the dust and looser dirt that they contain may be removed; and that the work of sorting may be easier and less disagreeable. There is no question of making these rags into piles that will be uniform throughout. They are sorted as they leave the

machine. Each bale of rags, as it arrives, is dealt with in its turn, and its contents when shaken are taken to the sorting boards (see Chapter IV.).

Like the teaser, the shaker is intermittent in its action. The door D (see Fig. 23) is opened and a quantity of rags put

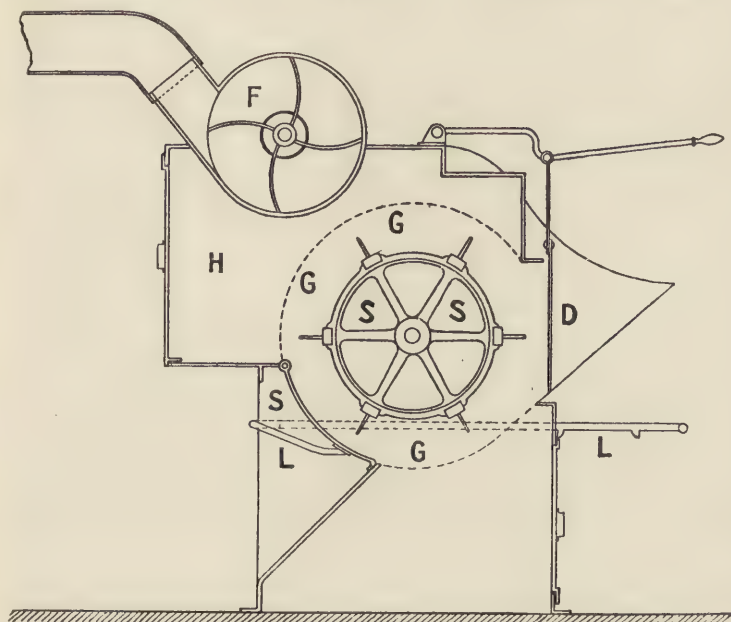


FIG. 23.—RAG SHAKER.

D. Door through which rags are put in.

S. 36-in. swift with 6 rows of pegs.

GG. Grid through which dust is sucked with the hopper H by the suction of the fan F.

L. Lever operating the lower door S, through which rags are thrown out.

into the machine. The swift S and the fan F are then set in motion, and the rags are left for 5, 10, or 15 minutes as the case may be, until the dust is loosened by the beating action of the arms and drawn away into the chamber H, outside the grid GG, by the suction of the fan F, which is employed for that particular purpose. When the operator thinks that sufficient time

has been allowed, the second door S is opened by the lever L, and the rags are thrown out on to the floor.

The Rag Machine or **Devil** are the alternative names applied to the machine which is used for grinding or pulling rags. Rags are here understood to mean all kinds of knitted or woven fabrics made of wool. They may have been made up into cloths and worn, or they may not. Some have formed parts of blankets, flags, and horse-cloths, whilst those known as tailors' clippings have never been in actual use at all. All of them come to the factory to be once more reduced to their original condition, when every fibre was separate from the others.

Grinding or "pulling" are the terms applied to this process, but both words are more or less misleading in regard to the nature of the work performed. It would be more correct to say that the rags are shaken to pieces by the action of the swift against which they are forced by the feed rollers of the machine. The construction of the devil is simple in the extreme. It strongly resembles a willey with only one toothed swift. The whole of the work is done at the point where the feed rollers B, B press the thick layer of fabrics against the pins of the swift S.

In a previous chapter it was stated that the very earliest machines were of very large dimensions, with swifts of 50 inches diameter or thereabouts. They ran at very high velocities, from 600 to 700 revolutions per minute. They were not covered with pins, but with plates that were cut into teeth, very much like a doffing comb. The writer has been unable to find out what was their usual width, but we are told that they were used before the days of steam and that they absorbed such an amount of power, that all attempts to drive them by manual power or by horse-gins failed, and water-power was substituted. At what

date pins were first used instead of plates is not exactly known, but for a good number of years the machines have altered very little either in size or construction. Illustrations from recent German works go to show that continental practice is nearly identical with our own; and it is highly probable that this country has set the example which is followed wherever rags are ground to-day.

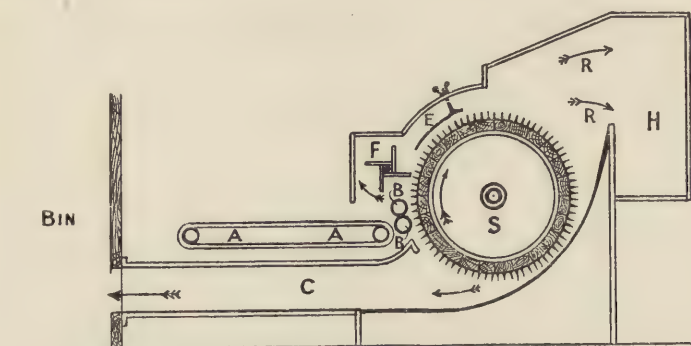


FIG. 24.—RAG MACHINE OR DEVIL.

- A. Feed sheet. Traverse (for merino) 20 inches per minute;
 " (for worsted or hosiery) 30 inches per minute.
 B, B. Feed rollers. Same speed as feed sheet.
 S. 36-in. swift, 18-in. broad. 700 revolutions.
 F. 12-in. fan. 1000 " "
 H. Hopper where unopened pieces of cloth are caught.

The dimensions which are here given show plainly enough that the working parts of a modern rag machine are relatively small. The swift is seldom more than 20 inches broad by 3 feet in diameter; it is nearly always built of lags of wood which are fastened to iron arms. The pins are of hardened steel, but so severe is the wear and tear on them that they are worn down to stumps in 16 to 20 weeks of continuous work. This means that the cost in depreciation is very heavy indeed, for unless each machine is provided with 2 swifts it must stand for a day or two each time that the pins are replaced. The cost,

of repinning is naturally considerable, and the machine must be adjusted afresh whenever the pins are renewed.

When a machine or swift is new its output is greater than at any other period of its existence, but this does not mean that it is necessarily doing the best possible work. The pins are rough, their points are square-cornered (see Fig. 25). They have a distinct tendency to cut the rags to pieces, breaking the threads and fibres, instead of beating the fabric until it is resolved into its original constituent hairs. Any breakage is of course a disadvantage, for the spinning value of all rag wool depends, like that of all other textile raw materials, upon its ultimate length. New swifts are therefore usually reserved for the treatment of the strongest materials, such as blankets and bunting; and their position is carefully adjusted in regard to the feed rollers.

As soon as a lot of rags is sorted and ready to be pulled, the various bags are taken to the pulling room. The contents of one of them are spread upon a stone-flagged floor covering a space perhaps 10 feet by 10 feet, and there it will be oiled. The amount it will receive may vary from 5 to 10 per cent., so that if the bag originally weighed one pack it will receive from $2\frac{1}{2}$ to 5 gallons of oil, together with an equal amount of hot water. The second bag, which is to help to form the blend, is spread upon the damp and oily layer made by the first. It will receive its due amount of oil and water. A third, fourth, fifth, and sixth bags will probably be treated in the selfsame way; each being spread and oiled and watered, until every portion of the pile contains a fair proportion from the various bags. It is then ready to be pulled. The novice's first sight of such a pile is apt to give him curious sensations. It is a greasy and unsightly mass, and one that gives but

little idea of the excellent quality of the finished article into which it is about to be turned. The man who "minds" the devil pulls rags only from one side of the pile, beginning at the top and working down in strips, so that the rags from all the various layers will go to the machine together. He straightens out the rags, and lays them out on the feed sheet A as flat as possible, layer after layer, until they form a *stratum* several inches thick. Thus they go through the rollers.

The friction, or the battering, of the pins against this mass of fabric generates so much heat that, in spite of the lubricating properties of the oil, the water all evaporates, and a small portion of the oil is also lost. A new swift, as has been already said, will cut or tear the rags, instead of beating them into a fibrous mass; and if the minder does not humour the machine, or if he tries to get the work through machines that are not suitably set for any special sort, he will not only have the pulling imperfectly done, but he will get very little weight through the machine. These devils have the weirdest way of rejecting work which is beyond their powers, throwing unopened pieces of cloth back on to the feed sheet as fast as they pass through the rollers.

It is but another instance that brains must be used as well as hands. Thin feeding often means more output, and not less. Correct cylinder speed is also absolutely essential to success. The feed of a new swift should be different to that of one which is partially worn, and, if possible, the nature of the material should be also different. This may be most easily illustrated by diagrams, for pins wear most upon the leading side, and points, quite square at first, soon take the shape shown in Fig. 26. When in this state the swift is at its

best. When it is too far worn, the bases of the pegs are only left, and as they are naturally thicker there is less space between them, quite apart from the fact that each point is broader and blunter (see Fig. 28).

It would be more correct to say that they would reach this condition if the swift were to run continuously in one direction. In practice, swifts are taken out and reversed once in four days, or once a week, or more, so that the pegs may wear away on both sides to form a needle point, as shown in Fig. 27.

The swift is at its best when two or three weeks old; the pins are then almost at their full length, but all roughness at

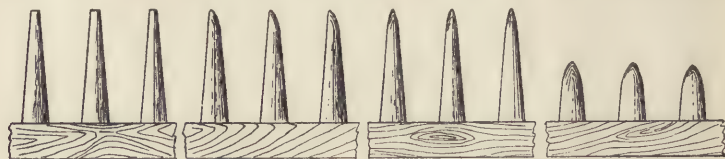


FIG. 25.

FIG. 26.

FIG. 27.

FIG. 28.

the point is rounded off, and the shafts smaller, but in other respects similar to those in Fig. 25. It is obvious that this shape will have little tendency to cut the fabric, whilst the beating power will be retained in full.

The curious action of the machine in returning to the feed board all pieces that it cannot open out thoroughly, is easily accounted for by any one who understands the principles on which it works. All separated fibres or threads that are light in weight are carried forward by the swift as soon as they are loosened from the cloth, and by the draught are carried nearly round the swift, and thence along the conduit C under the machine into the bin prepared for their reception. All larger pieces share a different fate. They, like the fibres, are dragged from the nip of the feed rollers the moment they

are loose, but their momentum causes them to fly at a tangent, instead of continuing in the draught, in the path of the pins; and the moment they are out of reach of the pins they strike against the wings of the fan, which immediately returns them through a gap in the cover to the feed sheet A. Still smaller bits of fabric, light enough to pass the baffle plate E, follow the course shown by the arrows R, R, into the receptacle H, whence they are taken from time to time.

With a swift whose pace and adjustment are entirely suitable for the work it is doing, it is astonishing how little material has to be returned. The mass of cloth that impinges on the pins seems rather to melt away before their action than to be ground or pulled to pieces, and it should, of course, be the object of the man who feeds the machine to attain this end. When he succeeds in this object the machine will be doing the largest possible amount of work.

The product of the devil is shoddy, mungo, or alpaca, as the case may be; shoddy being made from hosiery and other unmilled goods, mungo from milled cloth, and alpaca, or extract, from any class of material that has been carbonized. An immense amount of shoddy changes hands after this process. It is bought and sold in this condition, to be carded and spun by woollen spinners, sometimes alone, but more often after it has been blended with wool, cotton, or even with silk waste.

But on the other hand, the best rag-pulling factories are usually equipped with carding plant, and nothing in the whole range of the textile industries is more wonderful than the quality of the work that these machines turn out, when they are handled by a man who is really master of the art of carding. The pulled material as it leaves the bin goes

straight to them. Much of it is a simple fibrous mass, with every length of fibre represented; but pieces of soft yarn an inch or two in length, some bits of fancy twist, and even tiny bits of fabric, are certain to be found. All this heterogeneous mixture is weighed out by the automatic feed, and dropped on to the creeper. The first few rollers are usually clothed with garnett wire, and there the bits of fabric are pulled thread from thread. The threads are gently opened as they pass from coarser garnett wire to the rollers finer set, and finally to strong angle wire.

The principles involved are those discussed at length in later chapters, dealing with carding or scribbling; but the best shoddy machines are a class to themselves—they are very large, and therefore, lest readers should confound the system of clothing with the clothing of machines for scribbling proper, the particulars for this class of machine are given on page 218 and plate 58.

The least technical person must at once be struck by their immense size, for the width is 60 inches on the wire, and each contains four swifts, four doffers, and a breast, all of them over 40 inches in diameter.

It is a very common accusation that we in England do not understand the art of carding really short materials; at all events, this is the reason always given to account for Bradford's inability to make short tops like those that French and Belgian firms produce from South American wool. Bradford may be unable to produce short tops, but there are firms in Ossett that can turn out carded slivers made wholly from pulled wool, that are very nearly as free from neps as combed material should be. It is a triumph in the art of carding, depending in a very large degree upon the skill

and adaptability of the carding manager. But there is another point that worsted people seldom recognize in its entirety. Each lot (if perfect work is to be made) must go to scribblers that are *exactly* suited to its length and quality. Whilst Bradford prides herself on great adaptability, the woollen man provides himself with carding engines that are suited to some special trade, and kept for that alone.

The student will very naturally ask why, if some shoddy goes uncarded to be blended with cotton or with wool, other parcels should receive such an elaborate preliminary carding. This depends entirely on the class of work, or how perfect the blend is expected to be. It has already been pointed out that there can be no perfect colour blending until all the various individual fibres are free to blend indiscriminately throughout the mass; and that this is impossible, so long as threads of any kind are visible. It is a point rather difficult to make clear in writing, but it is one that can be easily understood by any one who has seen the shoddy when it is simply pulled, and also seen it after the same material has been treated by a proper card, properly set, and correctly speeded.

CHAPTER VII

MIXING

WHAT is the difference between woollen and worsted? This is a very common question, and by far the simplest, truthful answer is, that worsted is combed and woollen is not. There are, of course, many other ways in which the two trades differ. The difference of the greatest technical importance is the relative number of operations in the two processes. Not only do the number of the processes differ widely, but the nature of the various operations are also of a different character. It has already been noticed that in almost every kind of worsted machines, the slivers are not only extended in length, but they are also doubled, to ensure more perfect levelness in the finished thread. This putting up of three or more ends in every "box," in which the sliver is reduced in size, or extended in length, has no counterpart in the woollen trade. If, for example, a 50-pack blend of combing wool was to be made from 20 packs of P.P. greasy, 20 packs of P.P. scoured, and 10 packs of Adelaide greasy, the first half ought to contain 10, 10, and 5 packs respectively.

Owing to carelessness, let us suppose that the 5 bales are forgotten until 10 bales are washed, and the first portion is ready for the combs. What is to be done? The lot is simply run out, and the second half is made up 10, 10, and 10. This is carded, and in the comb, two ends of the first

part are blended in with every 3 ends of the second; or better still, the two might be combed up separately, and mixed in proportion 2 to 3 in the drawing. If this were done, the resulting yarn would be absolutely uniform throughout, and exactly the same thing might be said of a blend of various colours.

No such method of rectifying a mistake is possible in the woollen trade. There is no holding of stock between the scribbler and the condenser, and an hour after the first wool has entered the first machine, condensed rovings are ready to be spun. Nothing can be added, or taken away, to alter the quality or colour, and if the early part of the blend contains more light or less dark wool than the end, the first cops are certain to differ in shade from the last. It is for this reason that mixing plays such an important part in woollen spinning. All the materials that are to constitute a given lot should be ready before the first blend is made. If the lot is so large that it cannot be made into a single pile, each quality or colour should be divided into as many equal parts as there will be piles in the lot. This ensures that every pile contains exactly the same amount of each different quality, and it only remains to blend the various lots uniformly throughout each pile as it is constructed. Blending or mixing almost always takes place behind the teaser, after each lot has been through the machine. Lecturers usually assume that wool is being blended with mungo, or shoddy, or even with cotton or silk. It is true that this is generally the case. But if scoured and greasy wool are being spun together, the operation is none the less necessary. The quality or even the length of the two may be identical; but even so, the spinning value may be different.

To take the simplest possible illustration, let us suppose that 50 packs of scoured lambs are to be blended with 50 packs of greasy fleece for 50^s West of England yarn. Few mixing rooms are large enough to hold a pile containing 120 packs. Twenty packs would be a pile of more ordinary size, and in that case each pile would contain 10 packs of each type of wool. If they are blended before scouring, two packs of greasy would be teased and spread upon the floor, covering an area 12 feet by 12 feet. It might be 6 inches in thickness, and should be uniform in depth throughout.

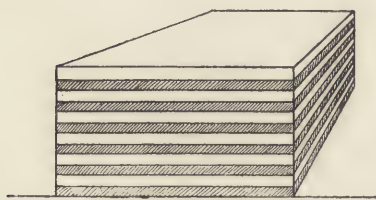


FIG. 29.

Two packs of scoured should next be teased and spread evenly upon the greasy layer. As it is lighter, it will stand, say, 9 inches thick. Next come 2 more packs of greasy and 2 more packs of scoured, the operations continuing, until a pile of 20 packs is made, having alternate layers of the two qualities from the bottom to the top (see Fig. 29).

It now only remains to take the mixture in even quantities from the side of the pile, to secure perfect uniformity of the whole 120 packs. This end is attained by pulling the wool by hand from one end of the pile, beginning at the top and working down until a strip, say, 6 inches thick by 2 feet wide, has been removed. Section after section is taken from the front in this way, until the whole pile is used up. If this course is followed, no one need fear that there will be any irregularity in the quality or colour of the yarn. The mixing of colour blends, in which the proportions are more intricate, must need no small dexterity on the part of the

workman and the manager; but in principle the process is the same, though there are several additional points that will need careful attention. In fancy woollen yarns, just as in fancy worsteds, silk and cotton play their part as well as wool; but whereas in the worsted trade comparatively little wool is carded after dyeing, it is very common in the woollen trade for dyeing to follow washing and to precede carding.

In addition to cotton and some little silk, we have also to take account of the immense quantity of "pulled wool" which annually finds its way into woollen fabrics. What the total proportion of shoddy and mungo is, compared with wool that has not been previously used, no one can tell; but in many districts in Yorkshire it must form a very considerable percentage of the total output of woollens, especially if the cotton, with which it is often blended, is taken into account.

The mixer must therefore be prepared to deal with almost every type of material—

Australian, Cape, and South American wool (usually carding quality).

Australian, Cape, and South American lambs' wool.

Fine merino wool noils, single combed.

Fine merino wool noils, double combed.

Camel-hair noils, alpaca and mohair noils.

Silk noils and waste.

Cotton, China grass, and other vegetable fibres.

And last, but far from least, an endless variety of shoddy, mungo, and extract wools.

All these widely differing types of textile fibres are blended in various woollen yarns. Sometimes the blend may contain 60 per cent. of cotton to help some poor quality of coloured shoddy, to make a yarn at 1s. 1d. per pound. Sometimes

Australian lambs may be mixed with double combed noils for the highest quality of West of England cloth, to cost not less than 2s. 6d. per pound. All the other fibres in the list will at one time or another be found in some of the endless styles that are produced. Long and short materials are much more often blended in woollen than in the worsted trade, and it is when a short, fine, black mungo is to be blended with white cotton and some longer wool, that the ability of the mixer will be really tested. In the first place, the wool and the mungo will each require a different percentage of oil; the cotton none at all. The wool will need perhaps a gallon to the pack, the mungo anything from 10 to 20 per cent. The mungo may be but a small proportion of the whole, and may be in two shades. Let us take such a mixture and see how it is blended. If there are to be—

5000 lbs. of short washed wool	at 2s.	=	^{s.} 20	^{d.} 0
2500 lbs. of cotton	at 1s.	=	5	0
1500 lbs. of black mungo	at 7d.	=	1	9
1000 lbs. of blue mungo	at 6d.	=	1	0
				20)27 9

The total cost of the blend would be . . . 1 41 $\frac{3}{4}$

If the blender be a man of experience, he will quickly judge how much floor space will be required for any given size of pile; but whatever area he selects, the ratio of each of the successive layers to the next must bear the same proportion. In every complete layer these must be—

- of wool, 50 per cent.;
- of cotton, 25 per cent.;
- of black mungo, 15 per cent.;
- and of blue mungo, 10 per cent.

If the whole is to be built into one large pile of 10 layers in thickness, there will be 300 lbs. in each layer of wool, 250 lbs. of cotton, 150 lbs. of black mungo, and 100 lbs. of blue mungo. When the 300 lbs. of wool has been teazed and spread upon the floor, oil will be evenly distributed over it from a can with as fine a rose as possible, until it has received a proper complement. If this is 5 per cent., the 500 lbs. will require 25 lbs. or $2\frac{3}{4}$ gallons.

On top of this, the black mungo will be spread in a uniform layer, of just such a thickness as will need 150 lbs., to give a uniform depth over the whole surface of the wool. But mungo, if it is to spin, must have a lot more oil than the wool requires. Fifteen per cent. would mean $2\frac{1}{2}$ gallons, and this must be carefully distributed before the cotton is added in its turn. Moreover, oil is fatal to cotton, and the less the contact of the one with the other, the better. The cotton in its turn is spread upon the mungo, and the first series of layers is complete when the 100 lbs. of blue mungo is added, and has been oiled. In different factories different methods of levelling consecutive layers are adopted, but the use of sticks, or hay forks, is very general, and probably has not yet been improved upon.

The pile now appears 5 yards by 5 yards in area, and, say, 15 inches in height. As was the case in blending two kinds of wool, succeeding layers are added one by one, each being an exact repetition of the first (see Fig. 30), until, say, a height of 6 feet is reached; this would include five complete and uniform series. As any greater

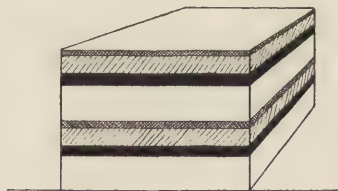


FIG. 30.

height would be very inconvenient, the pulling would now commence, one side being worked in strips, beginning at the top and working down until a slice had been worked right off one face. Sometimes this mixture goes straight to the teaser again, to be better mixed, and as that machine will deliver to either side, the blend will be ejected in a condition to be piled yet once again, or to be taken to the fear-naught or the scribbler card, as the case may be.

The student must under no circumstance conclude that the qualities and quantities given here are those of blends in use. Such a vast number of mixed qualities are produced that anything may be possible, although it may not be very probable. He must also remember that though 50 per cent. of wool to 25 per cent. of mungo is a possible proportion, he would be more likely to find the percentages reversed. This would, of course, reduce the first cost immensely. As the use of pulled wool is for the most part in the interest of cheapness, something like this is very likely to be seen in practice. But at the same time, it must ever be borne in mind that low first cost does not always mean the cheapest possible yarn. To show how greatly the price is affected by the proportions of the ingredients, a pile made of the same material is here reckoned out with the proportion of the qualities reversed—

	s.	d.
2 parts or 5000 lbs. mungo at 6 <i>d.</i> . . .	1	0
1 part or 2500 lbs. cotton at 1 <i>s.</i> . . .	1	0
1 part or 2500 lbs. short scoured at 2 <i>s.</i> . .	2	0
<hr/>		
4 parts or 10,000 lbs.	4	0 = 9¾ <i>d.</i> per lb.

This method of building piles in layers is so nearly

universal that it may be said to be an absolute necessity in every blend that contains two materials of different colour, or quality or length. The method of procedure will naturally vary slightly in different trades, but in principle the method is the same. The only complication in practice that need be mentioned, is that which is adopted where a very small proportion of some bright cotton of fine quality has to be evenly distributed throughout the bulk of a large pile.

Some colours, such as orange or vermillion, are of so vivid a nature that a very small alteration of percentage will make a great difference in the appearance of a blend. The difference between one-thirtieth and one-fiftieth of red and black would be quite a startling contrast, and therefore the utmost care must be taken in dealing with all vivid shades. It may be taken as an axiom that the more vivid the colour the less the amount that should be used in blend, and also that the less the proportion is, the more difficult will it be to blend it evenly through a pile.

Take an example. If 1 part of orange is to be blended with 32 of dark blue, in a pile of 10 packs, the smallest possible area would be 12 feet by 12 feet, with a height of quite 6 feet. If this were built into 8 successive layers of blue and orange, each layer of blue would be 1 foot in thickness, and each layer of orange would be in theory $\frac{1}{4}$ inch. It is, of course, utterly impossible to spread a layer of dyed wool of such a thickness uniformly over an area of 16 square yards. In places there would be a depth of 1 or more inches, in others there would be none at all. To get over the difficulty, it is common to begin by blending 1 part of orange with, say, 4 parts of blue. In this there is no difficulty. An 8-inch layer of wool is made, say, 9 feet square; then comes 2 inches

of orange, and so on, until a dozen layers have used up the 3 packs of orange and 12 packs of blue. Strips are then pulled from the face of the pile, say 6 inches thick, first A to B, then C to D, etc. (see Fig. 31), until the original face has been removed and a new face is left exposed. Thus layer after layer is removed in turn and thrown on to another pile, until the whole pile is used up; or it may be taken straight to the teaser. The blue and orange are in this way perfectly blended in the proportion of 12 packs to 3, forming a bright orange-

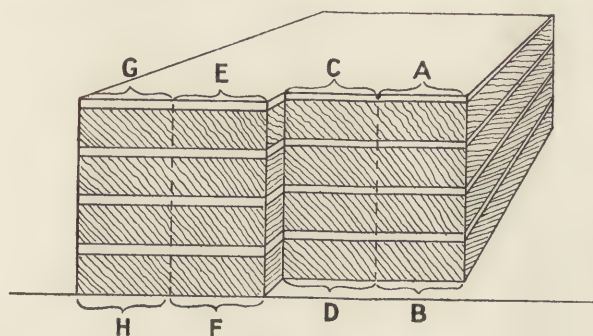


FIG. 31.

shaded blend. It now only remains to blend these 15 packs with the remaining 84 packs of blue, in exactly the same manner as already described, in layers that bear the proportion of 5 to 28, say 14 inches of blue then $2\frac{1}{2}$ inches of the blend or "mellowing," until the face of the pile is seen, as shown in Fig. 31. This must be once more pulled by hand, and the whole, after another teasing, or passage through the Fear-naught, will be ready for the cards, unless for special reasons it is thought worth while to build it into another pile, in horizontal layers, and once more use it by sections from the end.

However thoroughly this mixing may be done, no reader

must imagine that a homogeneous mass will result. The wool has been through no process that could separate the locks into individual fibres, and locks of orange could be sorted out from greatly preponderating quantities of blue. It can only be said to be uniformly blended, because every pound in the pile will contain the same percentage of the two colours. Probably many single ounces would be found that were not equally representative. This, however, does not matter. It is ensured that the card is always supplied with a charge containing correct proportions of both shades. In this connection a charge means a weight of material equal to the total weight of the wool that the card contains at any given moment, whilst working. This may be 3 or 4 lbs. in a 2-swift scribbler, and as many more pounds in the condenser card. Such a set might therefore be relied upon to complete the blending of any given lot of less than 4 lbs. in weight, and if every 4-lb. portion has 2 ozs. of orange distributed through it, the card may be relied upon to separate locks into individual fibres, and distribute them through the web of carded sliver or condensed thread, with so much uniformity that the eye can seldom detect irregularity. As a matter of fact, the blending power of a card will apply to far more fibres than are in, or on the machine at any given time, for some of the slow moving rollers may retain their hold on certain fibres, whilst other later comers go almost straight through the machine. This relates to principles of carding solely, and will be dealt with at length in a later chapter.

The question of applying oil is the only remaining detail that needs discussion under this heading. If all the lots that go to form a blend were known to require an equal quantity of lubricant, there would be little difficulty in having it

applied; but unfortunately some of the materials used in the woollen trade need a very large amount of oil, whilst others, such as cotton, are injured by it, and may even be contaminated by the presence of an excess of oil in layers that come adjacent to them in a pile or blend. Where blends are wholly composed of shoddy and mungo, or of shoddy or wool or noils, there is little to be said against the usual elementary system of oiling, still very general in the woollen trade, *i.e.* by means of a can with a rose spout. Such a lot of oil has to be added to each successive layer, that it can be done by an experienced hand with no small regularity, and is practised to-day in scores of factories. No one can say it is a very scientific method. All the oil falls on the top of a layer, and if this happens to be some inches in thickness, it must require a very considerable period before the individual fibres in the lower strata have absorbed their fair proportion.

All that can be said for such rough and ready methods, is that they are good enough in practice; and it is certainly true that oiling machines are very often conspicuous by their absence.

Vickerman stated very plainly that "when silk, cotton, china grass, or other extraneous fibre is required to be introduced, it can only be done safely and effectually by commencing the series of layers again, after the woollen material has been oiled and the oil absorbed." But it is clear that oil applied with a can must be a long time before it is uniformly absorbed or distributed, even if the pile is put once more through the teaser; and therefore, when a firm is under the necessity of dealing with large quantities of cotton blends, it may very well be worth their while to put in an oiling machine. We can easily believe that the maker of a

patent oiler would claim that his machine would distribute the oil so perfectly on to every fibre, that a less amount would lubricate a larger bulk of wool. To a spinner who wove his own yarn, this would be a very serious saving, for all the oil must of course be washed out in finishing the cloth. The more oil the yarn contains, the more will be the loss of weight in the finished piece, and the greater the cost in soap and in the amount of alkali needed to get it out. An oiling machine would probably pay in this case.

Where a spinner sells his yarns things are quite different. If he has a pile of wool and mungo that costs say $9\frac{3}{4}d.$, and if he adds thereto 10 per cent. of oil at $3d.$, he will of course increase the total weight, and reduce the total cost per pound to $8.94d.$ He is quite likely to improve his spin by the addition, and the cost of his yarn will also be less. He will therefore distinctly profit by the transaction, and until there is some standard in the trade for the application of lubricants, the can method is likely to remain in vogue.

So far, this chapter has dealt with the most improved methods of mixing, and it is based on the experience of firms who are most particular in the quality and regularity of their work, but any student who was left with the impression that such minute care is expended on every blend of woollen materials would be in a false position. The fact is, that the system already described is modified in many ways. In the number of layers, the thickness of each, and in the way they are oiled, there is possibility of endless variation. As an example, let us refer to the blend in which blue and black mungo were mixed with wool and cotton. After a layer of wool and one of cotton have been spread, some firms would bring a bag of each shade of mungo to the feed-sheet of the teaser at the same time. Two

men would be employed. One would spread black, the other blue, mungo on the sheet simultaneously, the two would be delivered on to the pile and formed into a layer of blue-black, equal in thickness to the two layers, one of blue and one of black, in the original pile as shown in Fig. 30. Of course, the weight of the two bags must be in correct proportion to one another and to the other material, and in addition, the men who feed must be expert, if it is to be quite certain that every charge of the teaser contains blue and black mungo in the proportion of 2 to 3.

Such labour-saving methods are widely adopted in the blending for low-class coloured yarns, where three or four colours of diverse quality and length are mixed together. Sometimes the quantities of each are very small, and the qualities so far apart that washed English wool and cotton laps may be mixed with black-dyed flocks. In such a mixture the length of fibres will vary from 8 inches to a $\frac{1}{4}$ inch or less, and the diameter from $\frac{1}{300}$ inch to $\frac{1}{3000}$ inch. As has already been pointed out, the teaser is not suited for opening long wool, and many fibres will be broken in their passage through the machine, simply because they reach across two or three pins of the swift, and in that position (see page 138) they are rushed against the intersecting teeth of the workers.

If the feed sheet is heavily loaded when such work is being done, the amount of wool to be broken is so great that the swift will almost stop, and the mixing will suffer in consequence. The best and cheapest results will therefore be obtained by feeding lightly and uniformly, rather than heavily. When sample lots are being done, it is common to feed a percentage of each of the constituents at one time on to the feed sheet, and to build them into a pile as they are shot from the machine.

As a matter of fact, such a blend should always go through a Fear-naught (see page 141) instead of going a second time through the teaser before it is taken to the card, for the teeth of the teaser are too far apart to open individual locks of wool, even if the staple is long. It is also quite obvious that cotton laps come out in very much the same condition as they go in. If a Fear-naught is used things are quite different. Staples of wool and cotton laps are very much opened and separated, and are therefore much more thoroughly blended than they are as they come from the teaser.

There is clearly a consensus of opinion that in practice almost all materials would be better if they went through both a teaser and a Fear-naught, and if it were only possible to lay down some equally definite theory in regard to oiling, it would be easy to suggest a satisfactory plan for setting out of an opening or preparing plant, but opinions regarding oiling are still in an archaic condition in the trade:—

First.—Shoddy and mungo are heavily oiled before they are pulled.

Second.—Sometimes oil is simply thrown from a bucket on to a pile before it goes to the teaser, and the machine mixes it well into all parts of the blend, leaving no material in such a saturated condition that it can do injury to cotton or silk.

Third.—The most imperfect, but the simplest method is to apply oil from a bucket after teasing, and toss the wool with forks to ensure a certain amount of mixing.

Fourth.—The application of oil from cans with rose spouts is only an improvement of this method.

Fifth.—The use of an oiling machine after or before the teaser is theoretically the best method, though it is

comparatively seldom adopted, because it involves additional labour and cost in power.

Sixth.—A system of spray oiling on the feed sheet of the Fear-naught is also recommended. This ensures the most economical distribution of oil over all parts of the blend, with consequent saving in the amount of oil required; but this system will apply oil in equal quantities to the cotton, as well as to the mungo and shoddy, and therefore it is not often seen in practice.

Obviously there are drawbacks to all the systems in a mill that does many qualities. All wool blends of washed material have oil applied as the wool emerges from the rollers of the final washing-bowl, and systematic oiling at that point either by hand or by machine is simple and satisfactory. In blends which comprise nothing but pulled materials, the difficulty of oiling is also reduced to a minimum. If it is desired to add to the amount of oil that the blend already contains, the surplus can be put on at any point, so long as it is well mixed throughout the whole. This is generally done before the last passage through the teaser, or before the Fear-naught, if one is used. It is the oiling of blends of wool and cotton, or of shoddy and mungo and cotton, that needs especial care. As cotton cards better without oil, and shoddy needs a very large amount, the application should take place in such a way that this end is secured. It is not easy to apply the oil uniformly until the materials have been opened by the teaser and spread upon the floor, and if the cotton is spread upon the shoddy immediately after it has been oiled the cotton must absorb a certain proportion of the oil.

The only way to avoid such contamination of the cotton is to tease the shoddy again after oiling, before the alternate layers

of cotton and shoddy are built into a pile, and the most perfect work would be done by—

1. Teazing the shoddy.
2. Running the shoddy through an oiling machine.
3. Teazing the cotton.
4. Building a pile of alternate layers of cotton and shoddy.
5. Running the blend through a Fear-naught.

Almost equally good work would result by—

1. Teazing the shoddy.
2. Oiling the shoddy by hand in the pile from a can.
3. Running the oiled shoddy again through the teaser.
4. Teazing the cotton.
5. Building a pile of alternate layers.
6. Running the blended pile through the Fear-naught.

This must make it quite clear to every reader that no hard-and-fast rule can be laid down. In the cheaper classes of woollen yarns, it is so essential to save wages, wherever possible, that no process must be introduced where it can be possibly eliminated. To be dogmatic as to the best routine would only show ignorance on the part of the writer, and a book can only be of service to a thinking man, in showing him how many methods there are in use at the present time, and leaving it to him to select the one that will save him all the expense that is possible, and is consistent with obtaining the best possible results, under any set of circumstances.

If the action of the teaser were continuous instead of being intermittent it would be very easy to apply oil mechanically, either at the feed sheet or where the wool was thrown out into the pile, but as the feed sheet is alternately standing and running, any oiling at that point would be very irregular indeed,

and it would be almost equally irregular at the delivery end. A simple oiling machine might be suspended over the pile itself, but the application of such a machine to the feed sheet of the Fear-naught is probably the best mechanical device yet known. Such a piece of apparatus is shown in Fig. 32. It is the well-known rotary brush motion. The oil tank D has a sight glass E, and a regulating tap, so that the amount of oil running into the trough in a given time can be accurately measured. The

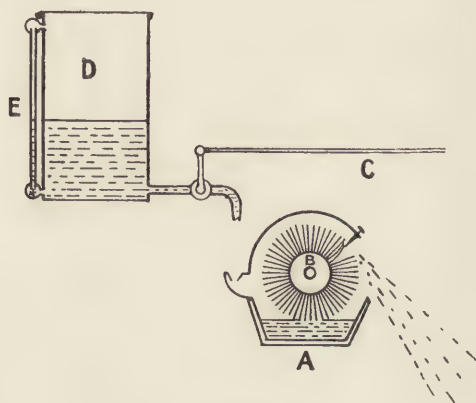


FIG. 32.

whole instrument may be fixed in any desired position so long as the circular brush B can pick up oil from the trough A as it rotates. Then as the bristles bend against the knife C, and spring straight on passing it, the oil which they have picked up is jerked off and thrown down in a fine spray, as indicated in the illustration. The spray may be made to cease automatically by driving the brush from some part of the machine which controls the delivery. If only the brush B is driven from some such wheel or wheels, and if a connection is made to the tap of the tank from the stop motion, the flow of oil may be shut off

at the same moment. If the sight glass is plainly graduated it is very easy to regulate the quantity of oil applied to any lot or pile of wool or pulled materials. Moreover, the oil is always falling as an almost invisible spray, so that every lock or fibre will receive correct allowance. None will have too much, and few, if any, too little.

CHAPTER VIII

CARDING

THE carding or scribbling and condensing which is practised in the woollen trade differs from all other carding of cotton or wool, in that there is no process between the condenser and the mule, whereas there are at least ten doubling or levelling processes in the worsted trade, and as many as eight in cotton, between the card and the spinning process proper. This means that any fault which occurs in the condenser will infallibly reappear in the spun thread, and it also means that any irregularity in the weight or amount of material fed to the condenser card will affect the thickness or weight of the various threads that are spun from the condenser slivers which the machine turns out.

Unfortunately, the worsted carder knows that any irregularity in his output will be rectified in the many doublings of the back-washing process, whilst imperfectly opened knots will be completely removed by the comb.

This is little less than a misfortune to the trade. It is probably the reason that England cannot compete with France and Belgium in the production of short B. A. and dry Cape tops; and it goes to prove how very little the two staple trades of Yorkshire make use of one another. The woollen carder, on the other hand, knows that all knots must be opened and

all irregularities of weight and colour obviated before the wool reaches the condenser leathers.

No excuses will avail if imperfect work has gone forward to the mule. This is a fact so obvious, that it is an axiom in every scribbling room. It is, doubtless, also the reason that woollen carding has attained a degree of perfection that compares all too favourably with the same process in the worsted trade.

It is fair, however, to say at the outset that this perfection of opening and separating fibre from fibre is attained at a price that a worsted man is not prepared to pay. Length is a factor in the spinning power of wool that receives too little attention in the woollen trade, and the breakage of long fibres is quite a common occurrence. The average length of the fibres that compose a thread bear a definite, though unknown, relation to the strength of that thread, provided that the twist is uniform. In other words, greater average length means greater strength with equal twist, or equal strength with less twist. But the greater the amount of twist that is inserted in a mule, the less will be the output, and consequently the greater will be the cost per pound of spinning. In practice the decrease in output may be only small, but it is none the less a decrease, and therefore unnecessary breakage of fibres should never be allowed, if it can possibly be avoided. Of course the woollen carder is heavily handicapped, whereas the worsted trade seldom mixes qualities and length that differ widely. The woollen trade will blend flocks, cotton, and Welsh mountain wool in one promiscuous pile, and send them to be carded by machinery that looks more fitted for a blend of fine lambs' wool and cotton. The worsted trade avoids all breakage in the carding process, and is prepared (often unnecessarily) to sacrifice something of

its opening power, in order to be sure of getting the greatest possible length in the finished "top." Whatever the woollen trade may regard as theory, it is often given to the breaking of the longer fibres in a blend, rather than run any risk that the opening or blending of colours shall be imperfect. Surely each trade might learn something of the other, and mutually profit thereby. The disinclination, or the inability, to do so is only one more proof of the innate conservatism of the "Tyke," who always likes to be regarded as a very "progressive" person.

The first object of woollen carding is to separate every fibre from other fibres which are next-door neighbours as they come to the machine. It does not matter whether these neighbours constitute a staple of new wool, arranged in the same order as when they grew on a sheep's back, or a strand of waste or thread that has already reached the end of one phase of existence, and is being once more turned into a respectable yarn. The process should so far comb all the fibres, that each is separate for its entire length from others, with which it has been associated. The more completely this can be done without any loss of length, the more perfect will be the result attained.

This separating of each fibre from its original neighbours must of necessity involve a blending with other fibres that, like it, are travelling through the machine, and will result in the production of a uniform web of threads, in which diverse colours and quality of fibre are promiscuously blended. To attain this end, it is only necessary that they have been fed in uniform quantities to the machine. This can only be secured by the most careful blending, as already described. Woollen and worsted carding differ widely from one another in yet another manner. In worsted it is the object of the carder not only to partially comb the wool, but to turn it into a sliver,

as nearly resembling a combed sliver as is possible. By this we mean that all knots shall be opened with as little breakage as possible, and that the fibres that compose the resulting sliver shall be as nearly parallel to one another as possible. This is necessary in order that the work of the comb may be easier, and result in a compact and uniform rope or twistless sliver.

In woollen, on the other hand, the reverse is the case. As already pointed out, every yard which comes from the doffer, must be equal to every other yard from the same lot, no matter whether it is from the beginning or the end of the same. There is, however, no desire to get the fibres parallel. The object of the process is to produce a series of slivers, each of which shall be of the greatest possible *bulk* in relation to its weight or length. The less parallel the fibres are that compose these slivers, the greater will be the bulk of the thread.

The free ends of fibres are very apt to protrude from a woollen sliver or thread, and this is never regarded as a drawback. It is, in fact, often made a distinct object to be attained.

If summarized in a few words this means that in a woollen thread:—

1. All fibres must be separated from their original position in fleece or thread.
2. All should be interlaced and mixed to the greatest possible extent.
3. To have the greatest possible length of individual fibres is not considered a desideratum, and in some cases is considered positively detrimental.
4. Fibres of different quality and length must appear uniformly throughout every part.
5. Fibres of every different colour in a blend must do the

same, so that every portion of every thread may be of the same shade or hue.

6. In order that every yard of every thread may be of exactly the same weight or size, the weight of wool being taken from the last doffer must always be exactly equal. In addition it must be equally distributed over every portion of the clothing of the doffer, or if the doffer be clothed with rings, every ring must be equally loaded.

These six objects are attained in practice by means which may be classed under eight distinct heads.

1. The number of working rollers in the engine.
2. The sizes of the rollers.
3. The number of wires per inch with which each of them is clothed.
4. The direction in which the wires point.
5. The surface speed of the rollers, or the speed at which the points of the wire pass one another.
6. The relative direction of the surface motion of various rollers at the point where they pass one another.
7. The distance of the wire points from one another at the point of "contact."
8. The method and regularity with which wool is fed into the machine.

Doubtless the ideal method of expounding the action of the card would be to discuss each of these eight heads separately, but many of them are so intimately connected with one another that it is impossible to treat them as if they were separate factors.

The eighth head will involve a chapter to itself, for it not only comprises the numerous automatic machines, that weigh out a given amount of wool on to every succeeding foot of the

feed sheet, but it includes all the various methods by which the sliver of a scribbler or "intermediate" is transferred to the feed sheet of the succeeding machine. It includes also the arrangement made to suit the requirements of special trades, by placing the wood in layers, overlapping or parallel, diagonal or longitudinal to the direction of the motion of the feed sheet.

So much has been said by other writers as to the different characteristics of wool and vegetable fibre, and their effect on the various processes of manufacture, that a brief mention of the difference between cotton and wool is doubtless desirable, although it is totally impossible to prove what part these qualifications play in the principles of carding power.

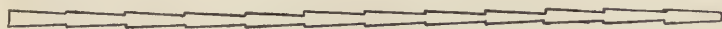


FIG. 33.

It is well known that if a human hair be rubbed gently between the finger and thumb it will "walk" slowly but steadily in the direction in which the root points. This is due to the arrangement of the scales on the surface of every single wool fibre. Wool is covered by scales which considerably resemble the scales of a fish, their free edges being always furthest from the root or hair bulb. Diagrammatically they may be represented as in Fig. 33—although the projection of individual scales is seldom more than three or four per cent. of the total diameter of a fibre; in the case of 64^s merino say $\frac{1}{20000}$ inch. Unfortunately there is nothing whatever to show the importance of the part they play, if they play any at all, for instead of being rubbed by two plain elastic surfaces, they are being treated by a vast number of wire points, all inclined to one another in such a way that the most refractory fibre is bound to move in their direction. It is moreover a well-known

fact that pure cotton, or a blend of cotton and wool, can well be carded on fine woollen machinery, and cotton is entirely destitute of scales.

Wool has another characteristic that is, however, of great value in spinning, if not in carding.

That is its waviness or crimp. As merino grows on the sheep's back its points usually extend less than two-thirds of its total length from the skin, the fibres occupying a position that is well represented by Fig. 34. It is only after washing and carding or combing that it reaches to anything like its greatest extension (see Fig. 35). Even then it distinctly shows



FIG. 34.



FIG. 35.

its wavy nature, and any fibre taken from a sliver, a thread, or a piece of cloth, will try to revert to its original shape if freely allowed to do so in a damp atmosphere. In woollen yarns this tendency is not only allowed full play, but the fibre is actually helped to curl and contract by the nature of the process.

Cotton is a much straighter fibre, but in place of waviness it has a spiral structure. It is not really flat, but in section resembles a crushed tube, and its spinning power is always attributed by practical men in the cotton trade to the twist that every fibre contains. Even fine Australian lambs' wool is longer than average cotton, but the spinning power of cotton is so great in proportion to its length, that there is every

reason to suppose that the theory regarding twist is a sound one. It is impossible to make any definite statements as to the part the properties of wool and cotton play in the carding process. But when the cotton and wool are blended and carded together, it is obvious that they behave in a very similar manner in the machine; and it may therefore be taken for granted that their respective peculiarities have little effect on their behaviour.

Wool and cotton are regularly carded together without difficulty on woollen cards, and practically pure cotton may go through these machines quite well. But no one has ever yet succeeded in working wool satisfactorily in a cotton "flat" machine.

The movement of wool or cotton through a card depends entirely on the position, condition, and motion of the wire points or clothing with which the card cylinders are covered.

When Rees wrote in 1819 hand carding was still in vogue. In describing the origin of the carding process he says, "The preparing of wool for spinning was probably first effected by the fingers and afterwards by the fuller's teazle or thistle, the *Dipsacus fullorum*, which, with its rough and hooked points, was well adapted to the purpose, and has continued in use to the present day. The card afterwards used was probably a substitute for the carduus or teazle." The original hand card must have been an exact counterpart of the hand board covered with teazles which is still to be seen in wool-raising establishments in the West of England.

In such a board the teazle heads are fastened closely together, with the hooked points or spines inclined in one direction. Long ago these teazles were replaced by wire clothing, which was arranged not only to imitate the spines

of the teazle, but to improve upon that arrangement by providing a surface more uniform and more evenly covered with teeth. The "cards" with which wool was prepared for spinning by hand, prior to the perfection of the carding engine, were either flat or slightly rounded boards, 8 inches by 5 inches, covered with card clothing of a primitive type and provided with handles.

If such a pair of cards were held face to face and moved across one another in such a direction that the teeth of one were point to point with the teeth of the other (see Fig. 36), it is obvious that any locks of wool placed between them would at once be caught at some point by the teeth on one of them, and so held that the teeth of the other board would card or partially comb the projecting ends.

If it should happen that a staple was first held by one extremity by either card, it is clear that many of the teeth of the other card would comb the staple and separate the various fibres throughout their entire length, leaving them in the very best condition for spinning if they could only be removed from the card without their relative position being disturbed. Unfortunately, in practice the staples are nearly always held at some point between the two extremities, and the separation of the fibres can never be complete until the staple has been moved from that position.

When the cards have been moved across one another a sufficient number of times to separate the fibres from one another, the wool will be found lying in the wire nearly parallel with the line of motion, and, as already stated, if it could be removed without being crumpled, it would be in the best condition for worsted spinning. Unluckily this is impossible.

The relation of the cards to one another is then entirely altered. The handles are brought together and the (see Fig. 37) motion is renewed. As the lower card moves towards X, its teeth slip easily past the teeth and over the fibres of the upper card B; but as it moves in the opposite direction, the teeth of A first clear the teeth of B, and then the teeth of B remove any fibres adhering to the teeth of A. A few strokes will serve to clear the straightened carded wool from both the

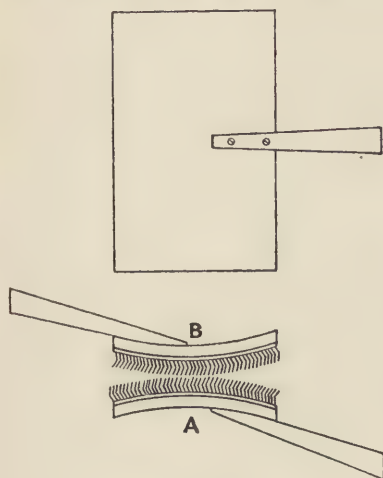


FIG. 36.

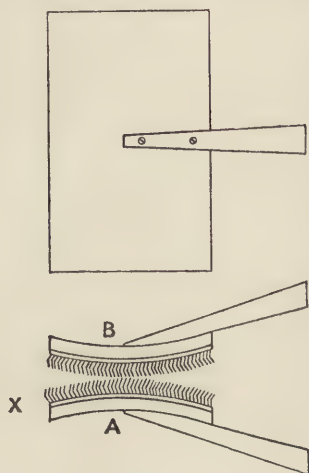


FIG. 37.

cards; but the wool will be straight no longer—it will be lying between the handles in a form much resembling a roll, which, though carded, will be in the best possible condition for the production of a bulky and serviceable woollen thread. The reciprocating motion of the hand cards in the first position (*i.e.* with the points of the wires opposed to one another, Fig. 36) illustrates perfectly the action of all the working rollers in a card or scribbling machine, and their action in the second position (Fig. 37) is exactly the same as is that of all the

stripping rollers. In one case the movement is parallel and reciprocating, in the other it is rotary and continuous.

In the hand cards, each in turn has to do duty as worker and as stripper, whereas in the carding machine there is a separate roller for each of these purposes. The clothing of the workers is being continuously filled by the swift as it rotates, and the wool which these rollers contain is, in its turn, combed by the wires of the swift. But it is clear that the worker

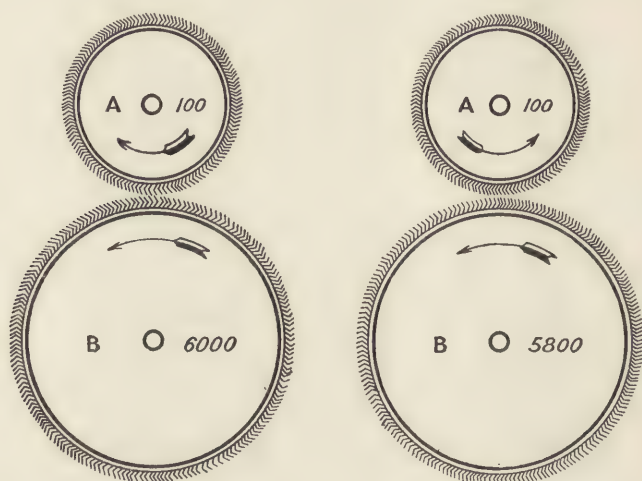


FIG. 38.

would soon be overfilled unless some means were provided to relieve it of its burden. This is the work of the strippers.

Speed and Direction.—The actual direction in which two *worker* rollers revolve in regard to one another is not necessarily the same in all cases, but it is absolutely essential that that part of the wires that is above the bend shall be inclined point to point (see Fig. 38).

A worker roller may retreat slowly before a fast running swift, but an exact equivalent in working power may be

obtained by its rotating in the opposite direction to a slower running roller. Thus, if a worker A is rotating with such a surface velocity that 100 of its wire teeth pass a given point in a second, travelling heel first, and a swift or other roller B is over-running it with a surface velocity equal to 6000 teeth per second, it is clear that there will be a working equivalent of 5900, and equally clear that if the worker roller A were to rotate in the opposite direction at the same speed (100 teeth per second) exactly the same result would be obtained if the swift continued to run in the original direction at a speed of 5800 teeth per minute—

$$5800 + 100 \text{ being } 5900.$$

The reader must not run away with the idea that he can calculate with mathematical accuracy the work done by any pair of rollers, but he may be quite certain that the amount of work is determined by the relative speed of the two rollers. Moreover, if their diameter and distance apart are the same, this relative speed will have a very important bearing in the work they do, provided that the number and sharpness of the wires in both cases are approximately equal.

Diameter.—In addition to the relative surface speed of pairs of working rollers, their size and their distance apart directly affect the quality of the work they do, because their working power depends very largely on the space during which the points of any two given wires are near enough to one another to do effective work, and this again, of course, depends on the length of the material under treatment. Let us suppose that the wool in the card is long enough to protrude so far from the teeth of the swift that it is first

touched by the worker, when the points of the two rollers are still $\frac{3}{8}$ inch apart.

In such a case it would be worked by all the teeth that pass one another during its passage from G to H in Fig. 39

—a distance of 4 inches if the rollers are 24 inches diameter. Put in other words, this means that if the wool is worked by all the teeth of the cylinder that are within $\frac{3}{8}$ inch of one another, two 24-inch rollers will do more work

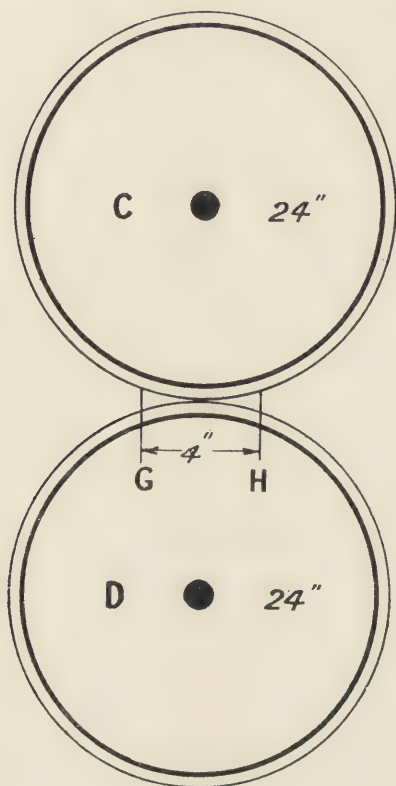


FIG. 39.

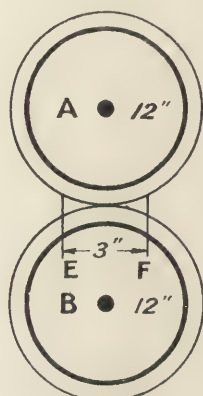


FIG. 40.

than two 12-inch rollers, because in the case of 12-inch rollers the part that we may call the $\frac{3}{8}$ -inch space (EF) is only 3 inches in breadth (see Fig. 40). This must not be taken to mean that there is any special virtue in the figure $\frac{3}{8}$. Some wools will be effected by working rollers at a much greater

distance, whilst others (such as short pulled qualities) will only be carded by the wires for a fraction of an inch on either side of an imaginary line connecting the centres of the two rollers.

It does not matter at all what distance is considered the limit with which material will be affected. Whether it is $\frac{1}{8}$ or whether it is one inch the rule applies equally. The larger the diameter of the roller the greater will be the time or space during which the wool or shoddy or cotton will be affected by the wires of the two rollers. If the rollers in Fig. 39 have 20 points per inch of circumference it is clear that in passing from A to B in the 24-inch rollers (Fig. 39) any wool which was fast would be combed by 4×20 or 80 points, whereas in the 12-inch rollers the distance is reduced to 3 inches, and, therefore, no lock could be treated by more than 3×20 or 60 teeth. It is unfortunate that the great speed of a swift or cylinder makes it impossible to form any idea of the actual distance at which work begins between the roller and its workers. It is also clear that the action of the stripper on the worker is not a fair criterion, and that in the breast, the wool is still so much in the form of locks that its action is also different. In the lickers of a worsted card wool is often caught when roller surfaces are quite an inch from one another, and therefore no data can be given that are of any value. For this reason no figures relative to this subject should ever be used in calculating the working efficiency of various parts of a card, though something should certainly be allowed for the omission. It is quite certain that larger rollers do more work than small ones, although the amount of extra work done cannot be calculated.

Setting.—When once a set of carding machines has been erected and clothed, its capacity for doing perfect work depends on three things—

First, the nature of the clothing.

Second, the sharpness or otherwise of the wire.

Third, on the setting or distance apart of the wire points, where they pass one another.

If it were possible to deal with subjects in their proper order, the particulars of the card clothing should be taken before its sharpening or setting, but as these particulars involve a mass of tabulated figures, it seems best to conclude the more theoretical part of the description of carding before passing to the purely practical, and as “setting” has a direct bearing on the last subject under discussion it is selected for treatment before the other two.

Given a suitable clothing and a smooth sharp point, setting is the most important part of a carding engineer’s profession. Setting refers to the adjustment of rollers in relation to their distance from one another. The important point is the distance of the points of the wire on one roller from the points of the wire on another roller with which it works, at the place where they are nearest to one another. This place is always on a line drawn between the centre of one roller and the centre of its neighbour, and therefore any alteration in the position of the shaft of a roller gives exactly the same adjustment to its circumference.

The first point of extreme importance is the distance between the cylinder and the workers (line 1, Fig. 41). The second is the relation of the fancy to the cylinders (line 2, Fig. 41). The third is the relation of the cylinder to the doffers (line 3).

In all these various rollers there is need for adjustment in only one direction—that is, along the line connecting their centres. Strippers, on the other hand, must be in correct position in regard to two other rollers. It must be possible to move every stripper nearer or farther from the centre of the swift (line 4, Fig. 41), as well as along a line connecting their centre with that of the worker that they clear (line 5).

A good card badly set may ruin the very best material. There are three entirely different ways of setting badly—

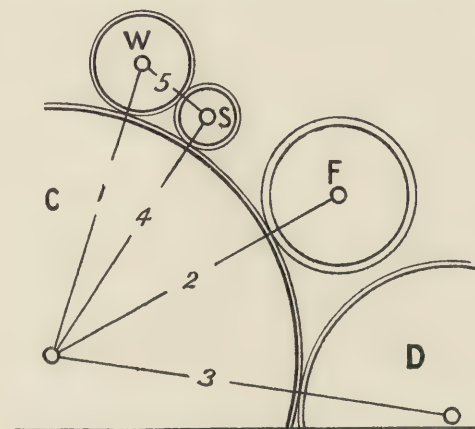


FIG. 41.

First, the centres of the rollers may be too near together.

Second, they may be too far apart ; or,

Third, they may be too near at one end, and too far apart at the other.

In the first case, the points of the wire will never come sufficiently near to one another to open the knots into which wool is invariably pulled in washing, etc. The carding will be quite imperfectly done, and it is certain to be neppy and uneven. To put working rollers too near together is a still

more deadly sin; the points of the one will immediately damage the wire of the other. The "point" of both will be quickly spoiled, even if the wires themselves are not bent back or actually torn away.

If we imagine an extreme instance of the third kind, we shall have the wire of the two rollers interlocking at one side of the machine, whilst they are too far away from one another to do good work, at the other end. Stated in this bald way, the supposition seems well-nigh impossible; but the student must remember that with an adjusting screw of 1 inch diameter and $\frac{1}{8}$ pitch (Whitworth standard), a quarter of a turn would make all the difference. The rollers of a cotton card must be so true that they may rotate within $\frac{1}{1000}$ inch of one another, but a quarter of a turn of an $\frac{1}{8}$ pitch screw would move the roller $\frac{1}{32}$ inch and make the wire touch. For this reason even the finest screws must be delicately handled when cards are to be set with accuracy. On the other hand, a space of $\frac{1}{8}$ inch between two rollers at either end would be fatal to really good carding; and it is for this reason that a first-class carding engineer must be a man capable of taking infinite pains in regard to what some people would consider to be paltry details.

Unless all rollers are of the same diameter at both ends, to within $\frac{1}{100}$ inch or less, the work of perfect adjustment is well-nigh impossible; and this, of course, depends not only on the accuracy of the rollers themselves, but on the preliminary grinding of their clothing. All these things must be matters of common knowledge to the carding engineer—matters that must never be lost sight of, the knowledge and practice of which will bring an extremely lucrative return.

When a carding engineer understands that a movement of

$\frac{1}{100}$ inch at either end of a roller is a matter of very serious moment, and that it may be sufficient to ruin the clothing of a cylinder, he will begin to wonder with what tool he is to be provided to ensure this perfection of accuracy.

In bygone days, a man was content to listen in order to hear whether any of the wires were touching one another when the machine was in motion. Such methods must be adopted with caution. It would be untrue to say they are obsolete in this country even now; but, fortunately for the success of the industry, the "gauge" is now in very general use, and setting is consequently much more scientific.

In the cotton trade, where setting is really reduced to a fine craft or science, electric gauges have been tried, which indicate contact by the ringing of a bell, but they are not largely used. The card-setting gauge resembles a closed 2-foot rule, but instead of having two sections each 1 millimetre thick, it consists of at least five blades, about 10 inches in length and about $1\frac{1}{4}$ inch in breadth. Each blade is carefully ground, and finished to be exactly equal in thickness to a standard size of wire; the numbers usually selected are 22 to 30, which means that the thickest blade is 0.028 inch in thickness, whereas the thinnest is only 0.012 inch.

The method of using a gauge is simple in the extreme. The rollers should be first set by eye with as much accuracy as possible. The gauge may then be applied. If the thickest blade slips easily between the worker and the cylinder, the rollers are too far apart. The screws at both ends are adjusted and the gauge is tried again; if the setting is now approximately right, No. 22 will not slip easily between the points of the wires. Considerable pressure is necessary. If No. 26 will go through with a great deal less friction—just so much that

a practised hand knows that the wires of both rollers do not do more than touch it at the same time—the end of the roller is set to gauge 26. No. 28 will go through without touching both rollers at once, and if 30 were inserted, there would be distinct play between it and the points of the wire on the two rollers.

When the engineer goes to the other side of the machine, he may find that the thickest gauge will not touch both rollers at once, and he must screw the worker down until the adjustment is exactly equal to that of the opposite side. He will

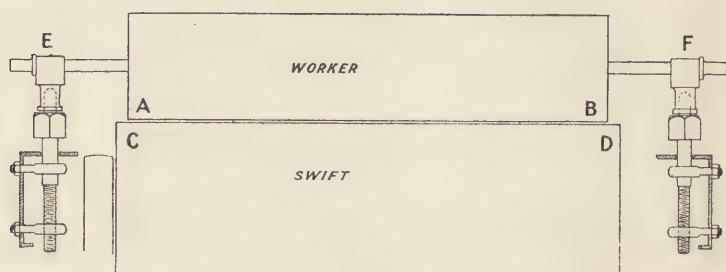


FIG. 42.

then run his gauge sideways between the rollers, and if they are correctly set, it will receive an equal amount of friction through the whole width of the wire surface.

It ought to be pointed out, however, that only a very slight alteration can be made at one end of a roller without affecting the other end also, and setting as described above would not bring two rollers parallel. If both ends could be adjusted at the same time, accuracy would be most quickly obtained; but this is seldom possible. The student must notice that the position of the bearings E, F is so far outside the clothing of the roller AB, that if a worker, was in proper adjustment with the swift at C, say $\frac{1}{100}$ inch above it, whilst

there was a space of $\frac{12}{100}$ inch at D, it would not do to lower the bearing F $\frac{11}{100}$ inch, because all parts of the roller would move some portion of that $\frac{11}{100}$. The point B being $\frac{6}{7}$ of the distance, FE would move $\frac{6}{7} \times \frac{11}{100}$, or about the distance that was required, but the point A would also move. It is true that the motion would be slight, because it is only 6 inches from the bearing E, and the total length to the bearing E is 60 inches; the movement would be $\frac{1}{7}$ of $\frac{11}{100}$, or $\frac{1}{63}$ inch, which is $\frac{1}{150}$ more than the $\frac{1}{100}$ that separated the rollers before the bearing F was moved. The wires in this case would touch the points of the other roller, the "point" would be lost and the work quickly ruined. The gauge must therefore be passed the whole width of the card from C to D before the machine begins to run.

These statements apply to the setting of all workers and doffers to the swifts, in woollen and in worsted cards, and also to the relation of the strippers to the workers and to the cylinders of worsted cards.

The setting of all stripping rollers in a woollen machine differs entirely from the setting of the same rollers in worsted cards. In the worsted trade the points of NO roller work into the clothing of any other roller, excepting only the fancy, which works into the swift or cylinder, for the deliberate purpose of brushing up the fibre that is lying embedded in the clothing of the cylinder, so that the fibre may be more easily caught by the wire of the doffer. This is also true of the fancys, in the woollen trade, whether they work on breasts or on cylinders.

In woollen cards, on the contrary, it is very common to work the points of the strippers into the clothing of the workers that they clear. The points may overlap or interwork

from $\frac{1}{16}$ to $\frac{1}{32}$ inch, or even more. This course not only results in the workers being kept constantly clearer than is the case in the worsted trade, but the practice has a more important, if subsidiary function. Stripping rollers always run very much faster than the rollers that they clear. The average surface traverse of a stripper is about 100 inches per second, whereas that of a worker is only about 2 inches per second, and the speed of a swift is 250, stated in the same terms. Now this means that the thousands of wires along the surface of the worker are constantly being rubbed by the wire of the stripper running between them. This action results in their smoothing and sharpening the points of the worker in exactly the same way that a steel sharpens a carving-knife against which it is properly rubbed. It also goes without saying, that the points of the stripper are themselves affected by the process.

The stripper is running point first into the wire of the worker, and the action that sharpens the points of the worker and smoothes away the roughness left by grinding, has a less satisfactory action on the stripper. If the worker and stripper were working point to point, the points of both would be ruined by the interworking; and in practice the point of the stripper is affected, although it has only to pass from the heel to the point of the worker wire.

When a new worker is first clothed, the respective points are blunt ended, just as the wire was cut off in the machine that made the clothing (see A and B, Fig. 43); and probably the marks of the cutter would be visible on the wire if it were examined under a microscope. In this condition it would not be sharp enough to remove the wool effectually from the cylinder. It is therefore ground with an emery roller to produce

a point, D, inclined in the same direction as that in which the wire leans, but the grinding flattens the top in a way that any one will understand who has tried the experiment of filing the end of a wire held upright in a vice. The point is perfect when seen in profile, but if it were examined end on, a microscope would reveal a burr or rough enlargement of the point (C), to which wool would stick. Practical men know the result of this very well. A new worker is not as efficient as an older one, and the reason is simple. The wires of the stripper, which are continually rushing between the points of the worker at a speed of 100 inches per second, soon rub



FIG. 43.

A, C, E, G, are front views of the same wires as
B, D, E, H, which are shown as seen from the side.

away the burred top until they make it smooth (see E, F), and then continue to grind down the body of the wire itself at its tip until the worker has a needle point as smooth as that represented by G and H. Any reader with a critical mind will at once conclude that the wearing will continue, and eventually reduce the length of the wire so far as to reduce its efficiency. Of course this is the case, but in practice it is found that the reduction is not so rapid as is the case with rollers that have no stripper working into them. They naturally lose their point in course of time, and have to be taken to a grinding frame and "touched" with an emery roller to keep the point as shown at D, Fig. 43. In practice

this is found to wear the wire away much faster than the inter-working of the stripper wire, and every one will see that the condition of the emery-sharpened worker is inferior to that of one which is pointed by its stripper.

If it were possible to conclude the matter at this juncture, it would seem that the woollen carder had discovered a "tip" by which he obtains no small advantage without any drawback, but this is not the case. The law of compensation still holds good, and the woollen trade pays a fair price for the method—a price that a worsted man thinks he cannot afford.

If the stripper could run heel first into the worker, both rollers would benefit by the mutual rubbing action; but because the stripper runs point first, its point is destroyed by the friction, very nearly as rapidly as the point of the worker is perfected. The extra cost of interworking may be reckoned without difficulty if the life of a stripper which works into a doffer or worker be estimated at twelve months. In a medium trade this seems to be a fair average. When a stripper first begins to work, after it has been ground its point resembles that of the worker in Figs. C and D. It is sharp, but it is burred. The friction of the worker wire quickly wears away



FIG. 44.

the burr and leaves the wire smooth, but by degrees the point is worn away as well. First it is merely blunt, but finally the point is really turned, having a lip or edge from which the wool cannot slip easily (I and J). This is the compensation! What are its effects?

Exactly as the stripper points the worker wire, so the cylinder is polished by the fancy, with one important difference: the fancy runs heel first, and only brushes up—never picks up—the wool from the cylinder wire. This means that

both the fancy and the cylinder have perfect needle points when they have run a while, if properly adjusted. The sharp teeth of the cylinder first take wool from the breast, carry it to the worker, and there give up a portion of their load. They then rush past the stripper, travelling twice its surface speed. Because the worker points are very smooth, the work of removing the wool is very easy, and a large portion of it remains above the points of the stripper. This is caught by the clothing of the cylinder, and its immense speed snatches it from the stripper with great violence. If the stripper had smooth points, no harm could, of course, result, because both wires are inclined in the same direction; but where a stripper has a turned-back point (see J), some fibres must be caught, and must, of course, give way or, put in other words, they would be cut by the turned point. In woollens, as has been already said, some shortening of the fibre is thought to be of little detriment, although in worsted nothing is more injurious to the spinning value of a top. This is the reason that the practice of these two sections of the trade differ so widely.

The action of the fancy F on the cylinder C so much resembles that of the stripper S on the worker wire W, that little need be added with regard to point alone. But as the fancy has an important part to play in lifting up the wool above the point S of the cylinder wire (in which it otherwise would lie quite straight, by reason of the speed), so it must have a setting quite peculiar to itself (see Fig. 44a).

The fancy differs from the stripper in that it runs heel first, not point first, through the wires into which it works. As in the case of the stripper and the worker, the wires may overlap or interwork by as much as $\frac{1}{16}$ or $\frac{1}{32}$ inch. But, in spite of their greater diameter, the speed at which the two pass one

another is much less. The surface speed of a stripper S may be 101 inches per second and that of a worker W only 3 inches, a difference of 98 inches per second. The surface speed of a cylinder C may be 262 inches per second and that of a fancy F one-sixth more, 306 inches per second. The difference here is 44 inches; and it is this difference, in conjunction with the length,

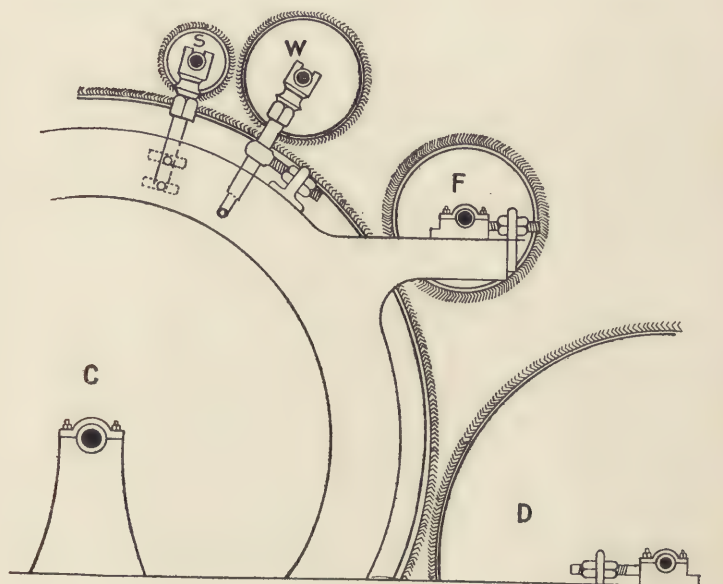


FIG. 44a.

pitch, and inclination of the wire, that gives the desired result. As each of the long springy fancy wires passes heel first through the wires of the swift it is brushed or rubbed by those wires from heel to point, until each wire takes a smooth, sharp needle point. The cylinder, likewise, is brushed from heel to point by the springy fancy wire, and it, in turn, is polished smooth and bright, though its stiffer, shorter wire never acquires the same needle-like sharpness as that of the fancy. It is just the kind

of point that is required (see G and H, Fig. 43), for practical men are well aware that when a cylinder is sharp rather than smooth it does not part readily with its load. They also know that an overloaded cylinder is fatal to good work.

We have now mentioned workers, strippers, swifts, and fancy as working into and polishing one another. All the rollers where the work is done are by this means brought to such a fine, smooth point that grinding is seldom necessary. As the stripper does not need to be very keen, it may be left out of account altogether. The last doffer, D, alone has no roller to polish it; but it is plain to any observer that many a woollen doffer has some agency at work that makes it shine exactly like the other rollers. This agent is the doffing comb, or knife, which is so set that its fine teeth go slightly below the points of the doffer clothing, not only removing the web of carded fibres very effectively, but also polishing up the points of the wire, so that they part readily with their load of wool.

Some people will expect that, in a work like this a writer should supply a lot of figures to make definitely clear the distance or the gauge at which every roller should be set from its next working neighbour. Such figures would be worse than useless. For, just because the art of setting cards is a fine craft, and not a hard-and-fast science, two men may reach the self-same end, (that is, to do perfect work) by slightly different means. Cards must be humoured by their managers. The counts, the crown, the speed and size must all at once be taken in account before the setting can be rightly done. No mathematical calculations, however abstruse, will ever solve the problem. In 1898 Mr. D. D. Marshall summed up all there was to say in the brief words "set near, strip clean, watch for effect, and study results,"

and however one might enlarge on that excellent advice the reader would be very little wiser. The figures mentioned on a previous page may be suitable for a super clothing 60^s; but this does not mean that 28 gauge is any use in a card that is doing mungo. A 36 may be used for every roller in the condenser, and if every roller in the two machines is set to the same distance, there is little fear that the work will be dirty.

Although it is always dangerous for a technical writer to be dogmatic; it is fairly safe to say that there is no more important problem in card management than the proper setting of a fancy. It is easy to see that, if the fancy inter-works too little with the wire of the cylinder, the wool will then be raised too little, and the doffer will not be able to take off its proper load; but people are apt to forget that in this case the cylinder is bound sooner or later to get over-loaded. Now, all writers are agreed that an over-loaded machine cannot possibly turn out good work. The workers and perhaps the strippers will choke, and finally the doffer itself will begin to remove the surplus material, from the cylinder, less perfectly carded than it ought to be, very possibly in lumps. This, it must be remembered, may happen when every roller in the machine is in perfect point and condition.

If a fancy is set too deep, the result is still more disastrous. It will lift the wool so much that lumps will begin to appear in the work in a very mysterious way. If the material is light coloured and of good quality it is easy to see that the lumps are of inferior and shorter material and the correct inference will be drawn; but where mungo is under treatment, the case is very different. The lumps will be similar in quality, and indistinguishable from the rest, in anything but their bulk;

it is only a really practical man who will go direct to his fancy, knowing that it is set too "hard on," and is therefore taking the "bottom" out of the cylinder.

When rollers interwork it is, of course, impossible to find their relation to one another by anything as accurate as a gauge, and it is equally difficult to work by eye when the points of the rollers are buried. There are, however, ways by which the depth of the fancy may be ascertained, and one of the simplest is here given—

The usual practice is to chalk a portion of the side of the cylinder—that is, the side of the wires—until the wires are uniformly white from crown to point. The fancy is then rotated, and if the wires of the two rollers overlap the points of the fancy will brush away the chalk, exactly so far as they extend, leaving a mark which exactly shows the "sweep" of the fancy, and the depth at which the longest points are working. It is then only necessary to adjust the two ends of the roller until both give exactly the same sweep.

These paragraphs are an attempt to analyze in words some of the many difficulties of carding. It is the most important duty of a carding engineer so to analyze them in practice that he can at once go to that part of the machine that is at fault. He must bear in mind that a smooth point is more important than a keen point, and that a fancy that is imperfectly set is the cause of many imperfections in the work. To those who understand the theories that have already been explained there is no need to say more; but theoretical writers are so often accused of being impractical, that one or two facts may be given for the benefit of beginners. The following statements are made to emphasize the importance of the fancy and of its accurate adjustment. It is no uncommon thing to

hear the doffers blamed for the bad work and for neps. Now, it is of course true that the neps are made on the doffer, but all the same, it is not the doffer that is at fault. Of the two it is rather the cylinder than the doffer that is to blame; but, if we analyze things back to the first cause, we shall find that the fancy is at the bottom of the trouble. It is probably set so lightly into the wire of the cylinder that it is hardly lifting any wool for the doffer to clear, and as a natural consequence the wires of the cylinder soon choke until, in the language of the trade "there is no mouth on the cylinder." It tends to roll the wool rather than take it from the preceding doffer and entirely fails in its duty.

This fault is by no means uncommon, and it is fortunate that it may be detected without difficulty by observing how quickly the card runs empty. If everything is in perfect adjustment the workers should "run clear" in six or seven minutes at the most, and if they continue to carry over any perceptible amount of wool, after that length of time, it may be taken as a positive sign that the functions of the fancy are imperfectly performed.

Grinding occupies a much less important place in woollen than in worsted carding. This is entirely due to the fact that the cylinders and doffers and workers of a woollen card are kept sharp by the wires of the strippers and fancys, which "work" into the wire of the rollers that they clear. The reason that this practice is not adopted for worsted has also been pointed out, and as our French neighbours adopt the same methods as we do, in setting for combed wool, it is safe to conclude that grinding is the only means to attain the desired end in the worsted trade.

In the woollen trade, grinding is almost entirely restricted

to the preparation of newly clothed rollers for work. However true a roller may be turned, and however well the clothing may be made, it is quite certain that the points of some wires will stand higher than others when the roller is revolving. These prominent wires have to be reduced to the length of the others by grinding, and all of them have their square ended point, A and B Fig. 43, taken off, so that they have a flat point directed in the same way that the wire is inclined, Fig. 43. As already pointed out, a smooth emery roller will do this very effectually, but at the same time it will produce a slight lip or curl on the sides of the point. This lip must be worn away

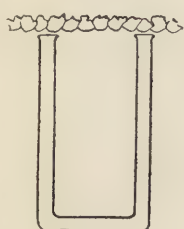


FIG. 45.

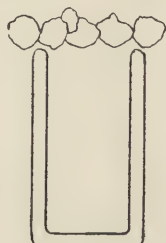


FIG. 46.

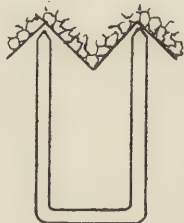


FIG. 47.

before the clothing can possibly do the very best work, and it is naturally an object with all grinders to avoid it altogether. The fine flat emery shown in Fig. 45 in the act of producing the curl or lip is often replaced by much coarser emery like that in Fig. 46. It is quite clear that the spring of the wire will take every point up into all the small inequalities on the surface of the roller, and the consequence is that a point is produced, more or less rounded, as seen from the back, but fine and taper if viewed in profile (see Fig. 43). In theory, at least, the most perfect point that can be produced with an emery roller is that shown in Fig. 47, where a grooved roller covered with fine grains is shown at work; the grooved surface of the

roller gets well between the points of the wire, and not only removes the lip or curl that is made by a flat surface, but actually helps in the formation of a diamond point, which is very efficient to work.

Workers, strippers, and fancys are always ground in a frame which is specially designed for the purpose; but cylinders and doffers should invariably be ground in their own bearings, so that there can be no possible alteration of centre when the

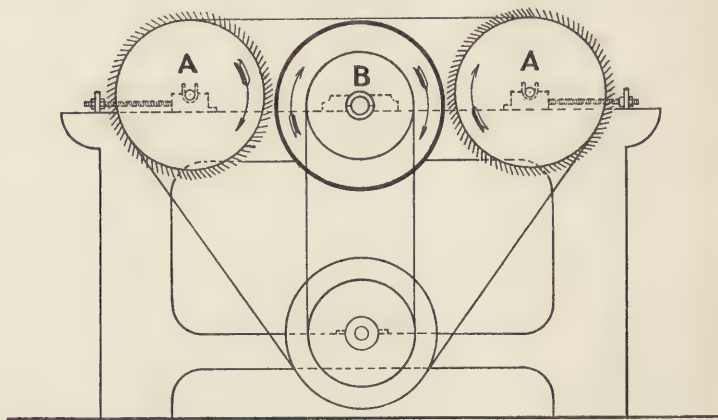


FIG. 48.—GRINDING FRAME.

B. 12-in. emery roller; say 450 revolutions per minute.
A, A. 10-in. workers being ground; 500 revolutions per minute.

operation is once complete. In work, some rollers are, of course, destined to run point first and some heel first. In grinding there is only one rule: the clothing of all must run heel first towards the emery roller at a speed of 200–250 inches per second. The emery roller rotates in exactly the opposite direction at a very similar pace. If a 50-inch cylinder is to be ground, this means that its normal number of revolutions (say, 100 per minute) is very suitable, but its direction of revolution must be reversed. A 10-inch worker, on the other hand, would

have to travel at 500 revolutions. To stand such a speed with safety, the grinding frame must be of a very substantial nature. The ordinary bearings in which a worker revolves at 4 revolutions per minute would be quite inadequate for the grinding (see Fig. 48).

Although the practice of grinding rollers whilst they are running at a high speed is almost universal for wool, it is only fair to mention the opinion of Mr. Leigh regarding cotton cards. He says, "The present system of grinding cards is quite unmechanical . . . the object acted on should turn slowly and the grinding roller quickly." This advice is opposed to practice in the woollen trade, and as Mr. Leigh says later on, "The way to overcome this important evil is not easily seen." It appears that he was propounding theory that had no basis in practice.

The second axiom in grinding is almost as simple as the first; the work must be done very gently. That is to say, the rollers must not be in contact when they begin to revolve. Adjusting screws must be so used in all cases, that the wire of the clothed roller is only brought so near to the emery that the most prominent points will be touched at all. The work must proceed so slowly that these protruding points are literally worn away before the roller is set to touch the shorter wires. If any serious pressure were applied, the longer wires would, of course, bend down in the foundation and remain there until, in work, the roller began to revolve point first. The wires would then be lifted at once to their original position, in which they would be so much longer than their neighbours that they would work into the neighbouring roller and at once ruin the point of both.

This question naturally raises a very important point, which is discussed at length on page 214, in regard to the making of clothing.

CARD CLOTHING is the term applied to the strips or sheets of fabric or leather which contain the pins or wire that do the work in a carding engine. Each pin or wire resembles a staple in shape, and its points being pushed through the "foundation." So full of wire is the clothing, that a small piece is more suggestive of a hair brush, with fine stiff bristles, than of anything else. In fact, it only differs from a brush in that the points are all inclined in one direction, instead of being vertical. Originally the ground work of all clothing was made of leather, into which the pins were inserted by the deft fingers of women and children. But the process was so slow and expensive that quite early in the history of the trade a man named Kay, of Bury, attempted, without success, to construct a card clothing machine. We are really indebted to America for the ingenious machine now in use, for the first one came to England from the other side of the Atlantic. It was purchased by a Mr. Dyer, of Manchester, and afterwards materially improved by a Mr. James Walton.

The advent of the machine had a very great effect on the materials used for "foundations," one of the best of which was Walton's own patent combination of cloth and indiarubber; the prototype of all the vulcanized foundations of the present day. From holding the place of first importance, leather was so quickly relegated to the second rank, that twenty years ago, in 1886, it was used for nothing but the sheets of fancy rollers.

Sheets.—When leather was the only available foundation, fillet was of course unknown, and all rollers were clothed with sheets; that is to say, with strips of leather about 6 inches wide, only the 5 centre inches of which were full of wire points (see Fig. 53). Through the edges on either side the tacks that fasten the leather to the wooden rollers of the engine were

inserted. These blank spaces or joints of course reduced the efficient working surface of every roller, and "fillet" was used for strippers, workers, and doffers at a very early date. Sheet-covered doffers were obsolete in 1880, but so conservative are we as a nation that the sheet-covered cylinder is still being made and used. This is in spite of the fact that a sheeted cylinder contains about 10 per cent. less points than one that is clothed with fillet of the same counts and crown. Moreover, as the cylinder rotates, the gaps in the wire create a draught that is anything but an advantage to the process. It is only fair to

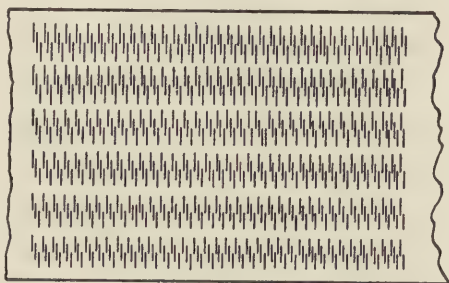


FIG. 49.—VULCANIZED RUBBER FILLET: RIBBED BACK.

say that sheets are decreasing so rapidly in popularity that a recent continental book does not even mention leather as a foundation at all. This will have made it clear that sheets are always nailed across the rollers parallel with their axis. **Fillets** are strips of fabric 1 inch to 2 inches wide, completely filled with points from edge to edge (see Fig. 49), so that when wrapped in a fine spiral round any size of rollers they form a perfectly uniform covering, in which it is difficult to distinguish the joints. The fabric of which they are made is composed of alternate layers of cloth and vulcanized rubber. The cloth may be of cotton or linen, or both. The thickness or number of layers may vary very greatly, but three to five layers of

cotton cloth may be taken as a typical sort. To secure adequate stability of the pins is the point of greatest importance, and it is for this reason that various trades need very different foundations. Only two examples need be given. Fig. 50 is a section of the foundation for a worsted doffer, covered on the top with a layer of rubber, whilst Fig. 51 is drawn on the self-same scale to represent the basis for a swift of Belgian style. In it the final layer of rubber is covered again with a layer of felt to protect it from the oil so freely applied to woollen yarns. It is made thick to support the wire, and also to avoid the necessity of "filling in" the clothing with "a mixture of ground

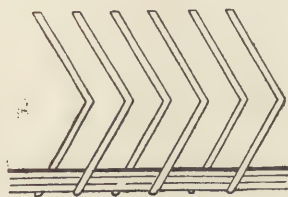


FIG. 50.

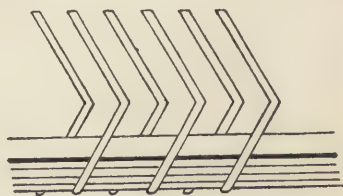


FIG. 51.

wool croppings, tallow and oil," applied by hand and beaten in with a stiff brush, which is the method recommended on the Continent, by theorists.

Originally all the wire used was made of iron. Now all is made of cold drawn steel, and much of it is plated with tin as well. This greatly extends the life of the rollers that have to deal with moist wool which is but little oiled.

The width of the fillet ought to vary with the diameter of the roller it is to cover. If wide fillet is used for small rollers (see Fig. 52), it is obvious that the crown of individual staples cannot be parallel with the axis of the rollers, and therefore the points above the bend must be directed slightly sideways, instead of being in the same plane in which they rotate.

This fact has been used as an argument for the use of sheets in preference to fillets, but if narrow fillet of $1\frac{1}{4}$ inches or $1\frac{1}{2}$ inches is used on rollers as small as 8 inches diameter, it is obvious that the alignment of the wire is only very slightly different from that which is theoretically perfect. The circumference of a worker is seldom less than 25 inches, and as $1\frac{1}{4}$ is only $\frac{1}{20}$ part of 25, the inclination of the crown from true parallel would only be as great as that of the dotted line shown in Fig. 52. This is so little as to be of no practical account in actual work, but nevertheless experiments have been tried with a view to correcting even this small departure from theoretic



FIG. 52.

perfection, by setting the wire at a slight angle to the side of the fillet.

If this were done correctly for an 8-inch roller, it is clear that angle would need to be 1 in 20, in order that the crown should be parallel to the axis of the roller when the fillet was in place; but it is equally clear that if this were used to clothing a doffer or even a stripper, the fault would be worse than with parallel built clothing, for a 40-inch doffer is 125 inches in circumference, and each lap would only be 1 in 100 out of parallel, with the crown inclined 1 in 20 in the opposite direction. In other words, clothing which would be parallel on an 8-inch worker would stand at an angle of 4 in 100 if it were used on a 40-inch doffer. This would mean that a different angle of crown would be necessary for every size of

thus 100, 10, 36 means that there are 20 points per inch and 10 staples, or 400 points of 36 wire per square inch.

In addition to counts, crown and diameter of wire, there are three other things of importance which receive much less attention than they deserve.

The first is what Mr. Leigh calls "keen," by which he means the angle at which the points are inclined forward. So far as the writer is aware, this matter is left entirely to the judgment of the clothing maker, and yet it is obviously a matter of vital importance in the working of the machine, for if the wire stood straight up no roller would take wool from its neighbour, and other things being equal, that roller which has its wire most

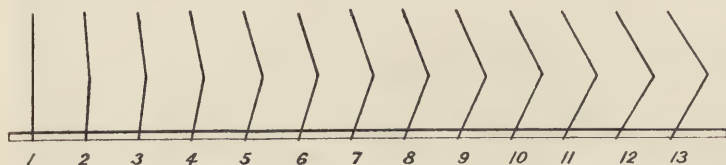


FIG. 54.

inclined will hold the wool the best. For reasons explained in the next heading, it is impossible to incline the wire forward from the foundations, and it was discovered at a very early date that the only way to obtain the desired angle was to bend the wire in the middle in such a way that its lower half leaned backwards at the same angle that the upper half inclined forward. Mr. Leigh gives a scale of inclination to explain this point, and it may be stated roughly that most card clothing would come within the angles of 3 and 8 (Fig. 54).

The relation of the point to the base of the wire is of even greater importance, and fortunately may be stated more definitely. Mr. Marshall says, "For general working purposes the wire that forms the tooth should be put into the foundation in

such a way that the hook which forms the working point should be exactly perpendicular with the shank or lower portion where the tooth enters the foundation." This rule applies to some of the rollers that are clothed with angular wire, and to all cylinders, doffers, workers, and strippers. The fancys, for reasons explained later on, are the only exception. Fig. 55 will illustrate Mr. Marshall's meaning. C is a correctly set tooth, because the "hook" or point is exactly perpendicular with the lower portion. Of D he says, if the tooth be set back or knocked back, it becomes totally unable to perform its proper functions, and is useless for any good carding whatever.

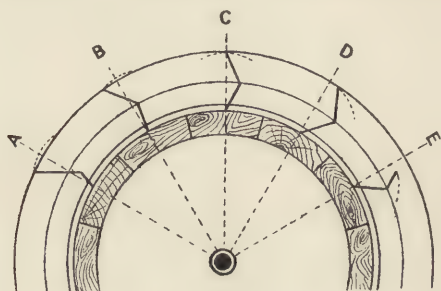


FIG. 55.

It is useless, but it is harmless, whereas the teeth that are set like B are useful but dangerous. The reason is easy to explain by the diagram, which is exaggerated slightly, to make the explanation more obvious. The pressure caused by the wool is invariably against the point, and this pressure causes them to lean back, their points moving in a circle of which the crown is always on the dotted radial line. C is correct, because if pushed back along the dotted line for 5 degrees, or even 10 degrees, its point is still approximately the original distance from the centre of the roller. D, on the other hand, as soon as it moves back, will at once

begin to recede from the solid line. This shows why it is inadvisable to work important rollers until the wire has been worn down nearly to the bend. If the wire has been bent, it will resemble the tooth D in Fig. 55; but if it has simply been worn away, the effect will be just as bad. The stump of the wire will stand as at E, and its extremity will be so far behind the perpendicular that it will fall away from the wire of its neighbouring roller the moment pressure is exerted against it. The wire B is the one that has already been referred to as dangerous. Pressure will cause its point to move along the

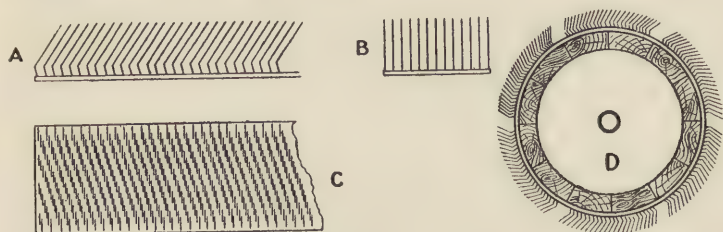


FIG. 56.

A, B, C. Side, end and back view of twilled fancy fillet.
D. Sheet covered fancy.

orbit or dotted line, and this orbit interlaces with the circumference of the adjacent roller. This means that the wires of the two will touch, and the point of both will be destroyed.

The fancy is the one exception to this rule, because it never has any pressure against its point. The pressure on the fancy wire A is always from behind, and therefore the greater that pressure on its springy wire, the less deep will it work into the wire of the cylinder. It is almost universal to set fancy wire as here shown, but it is an open question if this is the best possible position for all qualities and trades (see A in Fig. 56).

Size of Wire.—The third factor (mentioned on page 213)

is the size or diameter of the wire. It always increases in order to ensure greater strength as the wire decreases in count and crown; that is to say, that the fewer the wires the stronger they must be.

All these remarks apply to round wire rollers; many of the points to which attention is directed are also applicable to **angle or needle-pointed clothing**, for the feed rollers and the workers are much less closely set to one another than is

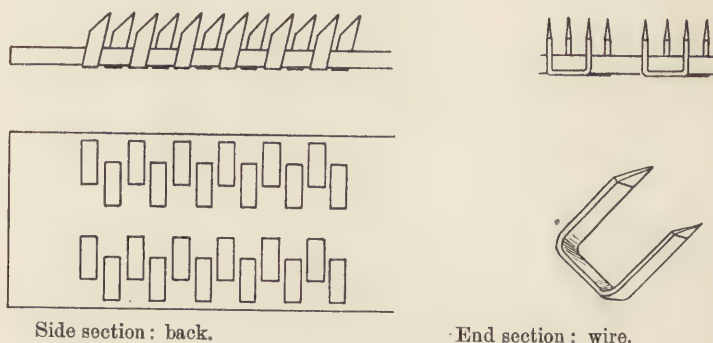


FIG. 57.—FEED-ROLLER FILLET.

the case of these more finely-clothed, and therefore it is permissible for the needle points of a feed roller, or those of a licker-in, to lean forward, as shown in Fig. 57.

This question of card clothing is one which involves so many considerations that almost any number of pages might be written on the subject. The clothing is of such expensive material that the complete covering of a single machine may involve an outlay of £200, and it is therefore of the utmost importance that those who are responsible for its use should know how to preserve the wire from destructive influences. Of these, rust is by far the most deadly. It is, of course, only caused by moisture, and as a great deal of woollen material

is treated without being washed, it is a disease that is more dreaded in a worsted than in the woollen trade, because it is most often developed from materials that are damp when they reach the cards.

Cards that are at work in a shed may easily suffer from drops of condensation that fall from a glass roof in cold weather, and it is also possible in damp weather, with extremes of heat and cold, that cards, standing empty, in an unheated room, may rust between Saturday and Monday. To have a set of carding engines standing empty for any length of time in winter may easily ruin them completely; simply because wire, even when tinned, will rust in time. When once wire becomes rusty it is, of course, too rough to be of any use at all for carding, quite apart from the fact that the rust will bind the wires so fast in the foundation that they lose all elasticity, and are useless for that reason alone. If card clothing loses its elasticity from this or any other cause, the action of the wool must bend the wire backwards and forwards, instead of moving it in the foundation. In this way fracture is sure to occur sooner or later, and patches will appear that are quite destitute of wire. Sometimes the fault shows first as a kind of pock mark on the rollers. The wire breaks out in spots instead of patches, but the reason is usually the same. Although rust is the chief cause of this evil, it is by no means the only one. If very stiff foundations should be used for the finest cards, or if the holes that are pricked for the wire by the card machine are too tight and small, the result is just the same. The wire has to bend instead of move on the base, as on an axis, and breakage will occur in time, though not so quickly as in the case of rusted wire.

TABLE XVI.

Particulars of Carding machine for Shoddy, with 4 parts and a breast.
For the treatment of pulled material as it leaves the "Devil."

	Number of rollers.	Size of rollers	Name.	Clothing.		
				Counts.	Crown.	Wire.
Breast part.	3	ins. $2\frac{1}{2}$	Feed rollers	Needle points		14
	1	12	Licker in	Needle points		14
	1	44	Breast	80	8	27
	3	9	Workers	80	8	27
	3	$4\frac{3}{4}$	Strippers	50	6	23
	1	12	Fancy	50	5	26
	1	36	Doffer	80	8	27
First part.	1	6	Angle stripper	50	6	23
	1	50	Swift	100	9	30
	4	9	Workers	100	9	30
	4	$4\frac{3}{4}$	Strippers	60	6	25
	1	12	Fancy	60	6	29
	1	44	Doffer	100	9	30
Second part.	1	6	Angle stripper	60	6	25
	1	50	Cylinder	110	10	32
	4	9	Workers	110	10	32
	4	$4\frac{3}{4}$	Strippers	60	8	27
	1	12	Fancy	65	6	31
	1	44	Doffer	110	10	32
Third part.	1	6	Angle stripper	60	8	27
	1	50	Cylinder	125	11	34
	4	9	Workers	125	11	34
	4	$4\frac{3}{4}$	Strippers	60	9	29
	1	12	Fancy	70	7	33
	1	44	Doffer	125	11	34
Fourth part.	1	6	Angle stripper	60	8	27
	1	50	Cylinder	130	11	35
	4	9	Workers	130	11	35
	4	$4\frac{3}{4}$	Strippers	60	9	29
	1	12	Fancy	75	7	33
	1	44	Doffer	125	12	35

See Fig. 58, page 222.

TABLE XVII.

Particulars of Carding set : Scribbler in 2 parts ; with breast ; 72 ins. on wire.
Condenser in 2 parts ; without breast ; 60 ins. on wire.

SCRIBBLER CARD (see Fig. 59).

	Number of rollers.	Size of rollers.	Name.	For low qualities, from 5 skeins upwards.			Revs. per min.
				Counts.	Crown.	Wire.	
Breast part.	3	ins. $2\frac{1}{2}$	Feed rollers	dia	mond	point	
	1	12	Licker in	dia	mond	point	
	1	6	Angle stripper	50	5	24	
	1	50	Breast	50	5	24	55
	4	9	Workers	60	6	24	$3\frac{1}{4}$
	4	$4\frac{3}{4}$	Strippers	40	4	24	270
	1	11	Fancy	45	5	25	510
	1	36	Doffer	55	5	25	10
First part.	1	6	Angle stripper	50	5	26	150
	1	50	Cylinder	80	8	28	65
	4	9	Workers	85	8	28	$3\frac{1}{2}$
	4	$4\frac{3}{4}$	Strippers	60	6	25	276
	1	12	Fancy	60	$5\frac{1}{2}$	25	510
	1	44	Doffer	90	8	29	8
Second part.	1	6	Angle stripper	60	6	27	150
	1	50	Cylinder	110	10	32	65
	4	9	Workers	115	10	32	$3\frac{1}{2}$
	4	$4\frac{3}{4}$	Strippers	80	8	30	276
	1	12	Fancy	60	7	30	510
	1	44	Doffer	115	10	33	6

Scotch feed

CONDENSER CARD.

First part.	2	$2\frac{1}{2}$	Feed rollers	dia	mond	point	
	1	12	Licker in	70	7	27	—
	1	50	Cylinder	120	10	32	75
	4	9	Workers	125	10	33	4
	4	$4\frac{3}{4}$	Strippers	80	8	29	290
	1	12	Fancy	65	6	27	510
	1	44	Doffer	120	10	33	6
Second part.	1	6	Angle stripper	80	8	28	150
	1	50	Cylinder	120	11	34	75
	4	9	Workers	125	11	34	4
	4	$4\frac{3}{4}$	Strippers	90	8	30	290
	1	12	Fancy	70	7	31	510
	1	44	Ring doffer	120	11	33	5

With rubber condensers ; or fillet doffer and tape condenser

The clothing specified in this and the following tables, is almost identical with that given by Mr. D. D. Marshall in 1898, but the size of the rollers has been considerably increased since he wrote. The counts named are those for which the machinery is most suitable. If it were used for thicker numbers the results would be less satisfactory.

TABLE XVIII.

Particulars of Carding set: Scribbler in 3 parts, with breast; 72 ins. on wire.
Condenser in 2 parts; without breast; 60 ins. on wire.

SCRIBBLER CARD (see Fig. 59).

	Number of rollers.	Size of rollers.	Name.	For medium qualities blends of wool, cotton, etc., from 16-40 skeins.			For work of the finest kinds, from 30-60 skeins.		
				Counts.	Crown.	Wire.	Counts.	Crown.	Wire.
Breast part.	3	ins. $2\frac{1}{2}$	Feed rollers		diamond	point	diamond	point	point
	1	12	Licker in		diamond	point	diamond	point	point
	1	6	Angle stripper	60	5	25	70	6	26
	1	50	Cylinder	70	7	26	80	8	29
	4	9	Workers	80	7	27	90	9	29
	4	$4\frac{3}{4}$	Strippers	60	6	25	70	7	27
	1	12	Fancy	50	5	24	60	6	26
	1	36	Doffer	80	8	28	90	9	29
First part.	1	6	Angle stripper	60	6	25	60	6	25
	1	50	Cylinder	100	9	31	110	10	32
	4	9	Workers	100	10	31	115	10	32
	4	$4\frac{3}{4}$	Strippers	70	7	27	80	8	29
	1	12	Fancy	65	6	28	60	6	28
	1	44	Doffer	110	10	32	115	10	32
Second part.	1	6	Angle stripper	70	7	26	90	9	30
	1	50	Cylinder	120	10	33	120	11	34
	4	9	Workers	125	10	33	125	11	34
	4	$4\frac{3}{4}$	Strippers	80	8	28	90	9	30
	1	12	Fancy	65	6	29	70	7	32
	1	44	Doffer	120	11	33	130	11	34
Third part.	1	6	Angle stripper	80	8	27	90	9	30
	1	50	Cylinder	125	11	34	130	12	35
	4	9	Workers	130	11	34	130	12	35
	4	$4\frac{3}{4}$	Strippers	80	8	30	100	9	32
	1	12	Fancy	70	7	32	75	7	34
	1	44	Doffer	130	12	35	130	12	35

Blamyres blanket feed

CONDENSER CARD.

First part.	2	$2\frac{1}{2}$	Feed rollers		diamond	point	diamond	point	point
	1	12	Licker in	80	8	27	90	9	30
	1	50	Cylinder	130	11	34	135	11	35
	4	9	Workers	135	11	34	130	12	35
	4	$4\frac{3}{4}$	Strippers	80	8	31	110	10	33
	1	12	Fancy	70	7	33	70	7	34
	1	44	Doffer (twilled)	135	11	31	130	12	35
Second part.	1	6	Angle stripper	90	9	33	100	9	33
	1	50	Cylinder	125	12	35	130	12	$35\frac{1}{2}$
	4	9	Workers	130	12	35	135	12	$35\frac{1}{2}$
	4	$4\frac{3}{4}$	Strippers	90	9	32	100	10	33
	1	12	Fancy (twilled)	70	7	33	70	8	34
	1	44	Doffer in rings	130	12	35	130	12	36

With tandem condenser; or fillet doffer and tape condenser

TABLE XIX.

Particulars of Carding set, Continental pattern: 3 single swift machines suitable for fine Scotch or West of England work, 72 ins. on the wire, up to 200 65-skein condensed threads.

	Number of rollers.	Size of rollers.	Name.	Clothing.			Revs. per min.
				Counts.	Crown.	Wire.	
Scribbler card.	3	in. $2\frac{1}{2}$	Feed rollers	Diamond point			1-5
	2	8	Garnett rollers	Garnett wire			
	1	8	Licker in	16 x 21 Diamond point			$7\frac{1}{2}$
	1	50	Cylinder	110	10	32	110-180
	5	$6\frac{1}{2}$	Workers	120	11	34	4-13
	5	$2\frac{5}{16}$	Strippers	90	9	30	620
	4	$2\frac{1}{16}$	Fly strippers	90	9	30	325
	2	8	Fancies	110	10	32	920-1120
	1	12	Small doffer	120	11	34	14-42
	1	$10\frac{1}{4}$	Small swift	120	11	34	200-450
	1	$6\frac{1}{2}$	Carrier	120	11	34	145-324
	1	$3\frac{1}{2}$	Burr roller	130	12	35	165-200
	1	36	Doffer	120	11	34	$2\frac{1}{2}$ -7
Josephy transmitter							
Intermediate card.	3	$2\frac{1}{2}$	Feed rollers	Diamond point			As above.
	1	8	Licker in	90	9	30	
	1	50	Cylinder	130	12	35	
	5	$6\frac{1}{2}$	Workers	140	12	36	
	5	$2\frac{5}{16}$	Strippers	100	9	32	
	4	$2\frac{1}{16}$	Fly strippers	100	9	32	
	2	8	Fancies	130	12	35	
	1	12	Small doffer	140	13	36	
	1	$10\frac{1}{4}$	Small swift	140	13	36	
	1	$6\frac{1}{2}$	Carrier	140	13	36	
	1	$3\frac{1}{2}$	Burr roller	130	12	35	
	1	36	Doffer	140	13	36	
	Josephy transmitter						
Condenser card.	3	$2\frac{1}{2}$	Feed rollers	Diamond point			As above.
	1	8	Licker in	100	10	32	
	1	50	Cylinder	140	13	36	
	5	$6\frac{1}{2}$	Workers	150	14	38	
	5	$2\frac{5}{16}$	Strippers	110	10	32	
	4	$2\frac{1}{16}$	Fly strippers	110	10	32	
	2	8	Fancies	140	13	36	
	1	12	Small doffer	150	14	38	
	1	$10\frac{1}{4}$	Small swift	150	14	38	
	1	$6\frac{1}{2}$	Carrier	150	14	38	
	1	$3\frac{1}{2}$	Burr roller	130	12	35	
	1	36	Doffer	150	14	38	
	Josephy tape condenser 200 tapes						

See Fig. 60, page 222.

TABLE XX.

Particulars of Carding set: Continental pattern, with 1 breast part, 1 swift, a transmitter and 2nd swift part. Suitable for medium Huddersfield qualities, 72 in. on wire. Up to 180 40-skein condensed threads.

Number of rollers.	Size of rollers.	Name.	Clothing.		
			Counts.	Crown.	Wire.
3	ins. 2 $\frac{1}{2}$	Feed rollers	Diamond point		
2	8	Garnett rollers	Garnett clothing		
1	8	Licker in	16 x 21 diamond point		
1	36	Breast	80	8	28
4	6 $\frac{1}{2}$	Workers	90	9	29
4	2 $\frac{5}{16}$	Strippers	70	7	26
1	8	Fancy	75	7	27
1	28	Doffer	90	9	29
1	8	Angle stripper	80	8	28
1	50	Cylinder	110	10	32
5	6 $\frac{1}{2}$	Workers	120	11	34
5	2 $\frac{5}{16}$	Strippers	90	9	30
4	2 $\frac{11}{16}$	Fly strippers	90	9	30
2	8	Fancies	110	10	32
1	12	Small doffer	120	11	34
1	10 $\frac{1}{4}$	Small swift	120	11	34
1	6 $\frac{1}{8}$	Carrier	120	11	34
1	3 $\frac{1}{2}$	Burr roller	130	12	35
1	36	Doffer	120	11	34
Josephy transmitter					
3	2 $\frac{1}{2}$	Feed rollers	Diamond point		
2	8	Licker in	90	9	30
1	50	Cylinder	120	11	34
5	6 $\frac{1}{2}$	Workers	130	12	35
5	2 $\frac{5}{16}$	Strippers	100	9	32
4	2 $\frac{11}{16}$	Fly strippers	100	9	32
2	8	Fancies	120	11	34
1	12	Small doffer	130	12	35
1	10 $\frac{1}{4}$	Small swift	130	12	35
1	6 $\frac{1}{2}$	Burr roller	130	12	35
1	36	Doffer	130	12	35
Josephy condenser, 160 tapes					

See Fig. 61.

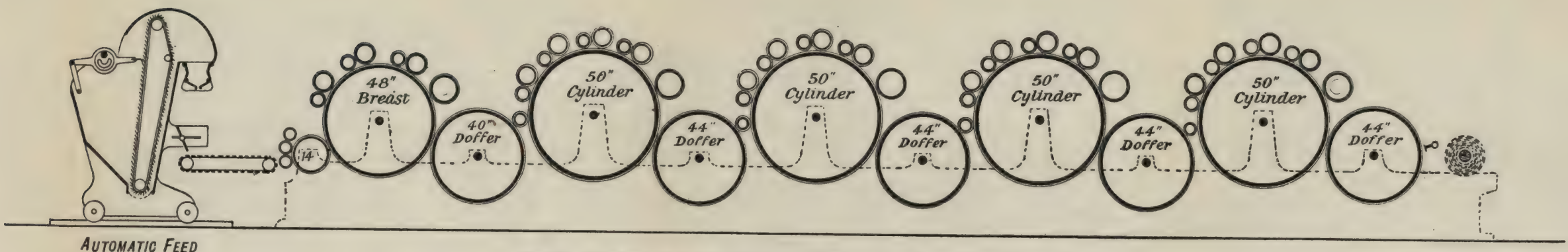


FIG. 58.—MACHINE FOR CARDING SHODDY, WITH BREAST AND FOUR "PARTS" (see p. 218).

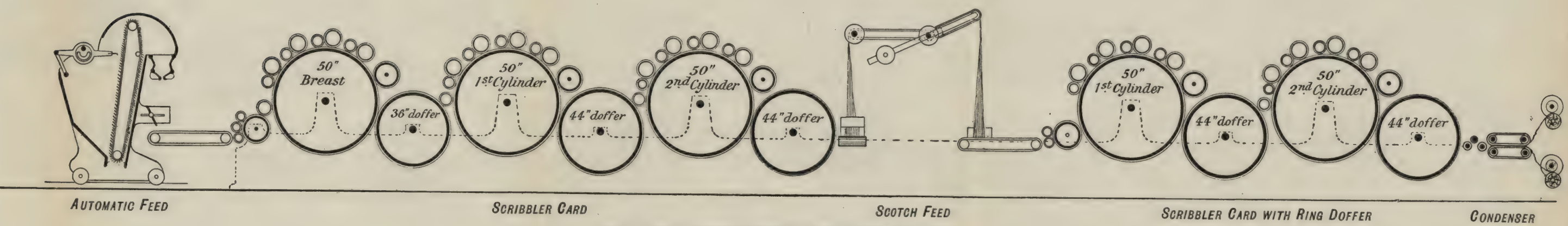


FIG. 59.—SET OF CARDING ENGINES FOR LOW QUALITIES (see p. 219).

Back of
Foldout
Not Imaged

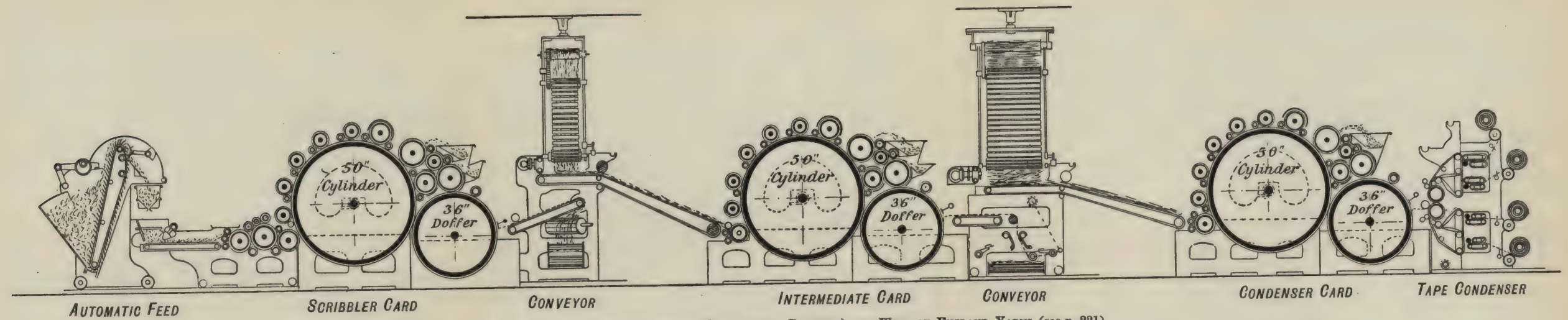


FIG. 60.—SET OF CARDING MACHINES (CONTINENTAL PATTERN) FOR WEST OF ENGLAND YARNS (see p. 221).

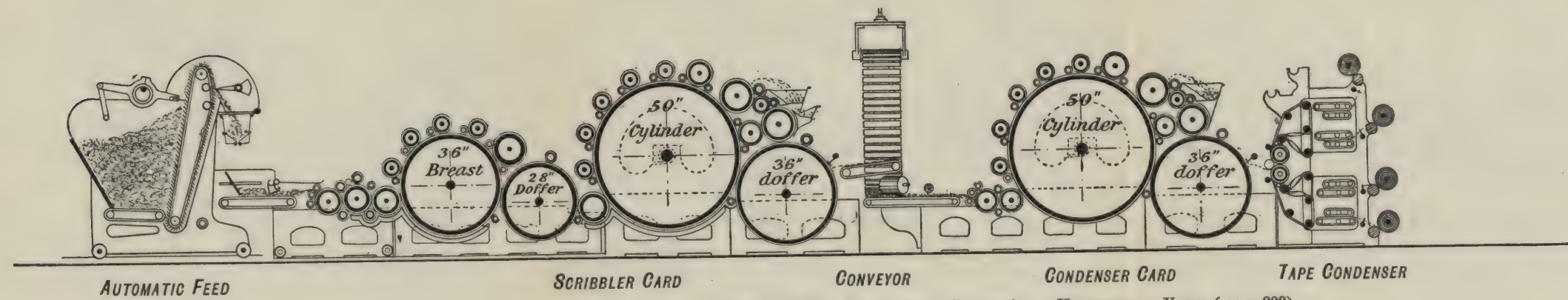


FIG. 61.—SET OF CARDING MACHINES (CONTINENTAL PATTERN) FOR HUDDERSFIELD YARNS (see p. 222).

Back of
Foldout
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CHAPTER IX

CARD FEEDS AND CONDENSERS

IT is impossible to lay too much stress on the fact that cards must be uniformly supplied with the material they are to work. It has already been pointed out that unless the various colours are distributed in equal quantities over the feed sheet, it is unreasonable to expect that the various condenser threads that come from one machine will all contain the same proportion of those colours. This means that there will be variations in shade. It is of even greater importance to remember that if the total weight of wool put on to the feed sheet during any one hour is greater than that which was supplied to the machine during the hour previous, it is utterly impossible for the threads that come from the condenser to be uniform in size, density, or weight.

In worsted, things are absolutely different; the product of one card might be 15 per cent. lighter than the product of its neighbour; and the product of both for one morning might be 25 per cent. less than the product for the afternoon, without making a single "top" irregular in weight. This is due to the immense number of doublings, or mixings in the numerous processes embraced by the comprehensive word, "combing." When we consider these facts, and realize that in spite of them the worsted carder almost always uses automatic feeds to make sure of a perfection that can hardly be described as

necessary, it seems hardly worth while to explain how much more important it is to have automatic feeding in the woollen trade, where there is no intermediate process between the ring doffer and the mule.

Before the advent of the first automatic feeding machine from America, it was customary to have all feed sheets marked into sections, and it was the duty of every carding hand to weigh out wool upon an adjacent scale, and place the same amount of wool on every section of the feed sheet. When this is well done by a skilful hand the result is very satisfactory; but as humanity is still exceedingly fallible, it is always the object of a manager to make errors impossible, by the action of automatic machinery.

The action of many automatic weighing feeds seems to be so nearly perfect, that a theorist would expect to find that all threads would be alike in weight, even if they came from a ring doffer applied to a scribbler card. But when he considers that every load that is discharged on to the feed sheet has to cover a space 4 inches to 8 inches wide, and 48 inches to 72 inches in length, he will see that it is unlikely that every portion of the lattice will be uniformly covered. As a matter of fact, there is no guarantee that both sides of the feed sheet receive equal weights (to a fraction of an ounce) at every charge, and though the differing speeds of the rollers have a great effect in blending the materials from successive sections of the feed sheet, they can only do this to a limited extent. It is therefore found necessary to introduce some apparatus between each pair of cards, that will blend together in the condenser, work that passed over the feed sheet of the scribbler during the space of minutes or even hours.

This chapter will therefore be divided into two portions.

The first dealing with machines that feed raw material to the scribbler with the greatest possible uniformity. The second being the nearest approach that there is in the woollen trade to the doublings that form so prominent a feature of the worsted process, though it differs entirely from the latter in one essential.

In worsted all doublings are so arranged as to accentuate the parallel alignment of the fibres in the thread; whereas in the Scotch and Blamires lap feed no pains are spared to feed the material to the condenser card with the fibres in a position that is transverse to their line of movement and to the axis of the thread they are to form.

AUTOMATIC SCRIBBLER FEEDS may be divided into three distinct types.

1. Those that supply wool direct from a box or hopper to the rollers of a card by means of feed rollers, workers, and stripping knives as in the Bohle type.

2. Machines that distribute a layer of wool of given density with uniform thickness on to the feed sheet or lattice creeper of the card. For example, see Lemaire's machine.

3. Machines that weigh out a certain number of ounces of wool on to a given number of inches of the feed sheet of the card.

So far as the writer can discover, the first patent for an automatic feeding machine was taken out by Mr. Bolette in 1864. To what extent it was actually used in Europe it is not easy to decide, but it was never generally adopted in this country or America, although it was improved by Harwood, of Boston, in 1875. The first really successful machine that was put on the market was patented in America in 1876, and may be taken as the prototype of all the weighing feeds; it being,

to all intents and purposes, a facsimile of what is called the Tatham machine on this side of the Atlantic.

Type 1, that supplies direct from a hopper on to the roller of the card, cannot be better represented than by an illustration of the **Bohle** machine. It is easy to see from Fig. 63 that the wool in the box **A** must actually rest upon a series of rollers that pass it from one to another, and are so stripped by one another and by the oscillating knife **F**, that a regular supply,

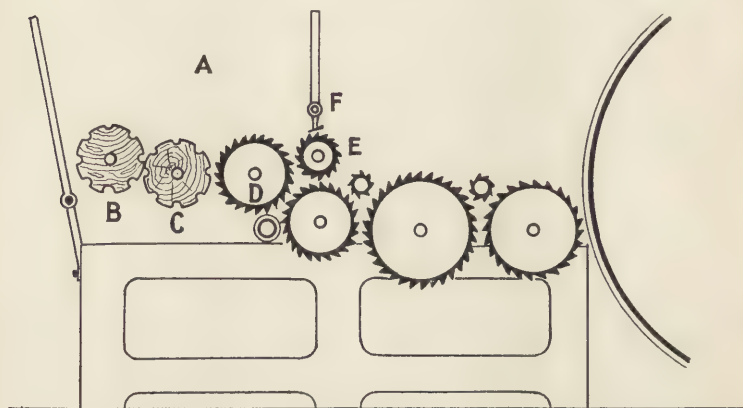


FIG. 63.—BOHLE FEED.

in the form of a thin layer of wool, goes slowly forward to the working rollers of the card.

B and **C** are merely feed rollers that carry the wool forward to the clothed roller **D**, which in its turn is partially stripped by roller **E** and the knife **F**.

The writer has no personal knowledge of this machine. It is, of course, unsafe to say that it is not in use in this country, but if it is safe to draw conclusions from the many mills of various types that are known to the writer, it is very scarce indeed; the third type, or weighing feed, being practically universal in this country.

Type 2, as illustrated by the **Lemaire** feed, takes precedence in Continental handbooks of weighing feeds, and as it stands halfway between the oldest and the most popular forms, it may well be considered second. Like the Bohle machine, it is very little used in this country. But its principles are so simple that they deserve consideration in view of the fact that they are applied indirectly to the Bramwell machine (see Fig. 64).

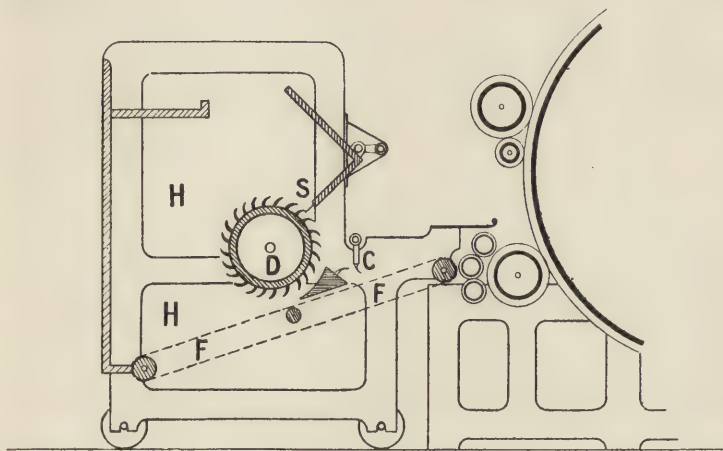


FIG. 64.—LEMAIRE FEED.

The theory is that the toothed roller *D* will always carry the same amount of wool past the swinging stripper combs, whether there is a full charge of wool in the hopper, or if only a few locks are being fed to the roller by the feed sheet *F* at the bottom of the hopper. A second swinging comb, marked *C*, removes the wool from the roller teeth and places it again on the feed sheet, to be taken to the feed rollers of the card.

Type 3 may be regarded as the only one that has any real hold in this country, and it is interesting to note that machines

on the lines of **Bramwell's** first machine are still being made and used.

Here we should pause to consider what things are essential in an automatic feeder.

1. It should weigh on to every portion of the feed sheet an equal weight of wool; but

2. It is possible to weigh $\frac{1}{2}$ lb. to every 8 inches in length of the lattice feed, and yet to give to one side considerably more wool than is given to the other. This would be absolutely fatal to the object of the machine in the woollen trade.

3. From a hopper that is full of a blend of long and short material, the machine must be guaranteed to take both long and short fibres in their proper proportions, whether the supply is great or small. Some exceedingly particular firms say that automatic machines never do this perfectly, but take an undue proportion of long fibre at first, and leave too much short at the bottom of the hopper for later delivery. This ought not to be the case, and there is little doubt that the best modern machines are practically free from this defect.

4. The motion of the feed sheet, the action of the swinging combs, and the shape of the hopper must on no account be allowed to roll the wool in the hopper. With short material this tendency has little effect on results, but with long wool it tends to entangle the fibres that have been separated in the willey or Fear-naught.

5. The machine ought to require little or no attention from the time the hopper H is filled with wool until it is very nearly empty.

Two machines on the lines of **Bramwell's** patent are shown in Figs. 65, 66. The creeping lattice G has pins on every lag, and carries wool up from the hopper H until it meets the swinging stripper comb S, whose duty it is to remove adhering lumps

of wool, and only to permit a uniform quantity to find its way into the pan P. If the comb S is doing its work well, every portion of the sheet G will take over an equal quantity, and the pan P will be uniformly full from end to end; but if the comb is badly set, so that it is farther from the sheet at one end than it is at the other, or if some pins have been knocked out of the sheet on one side, then one end of the pan will contain

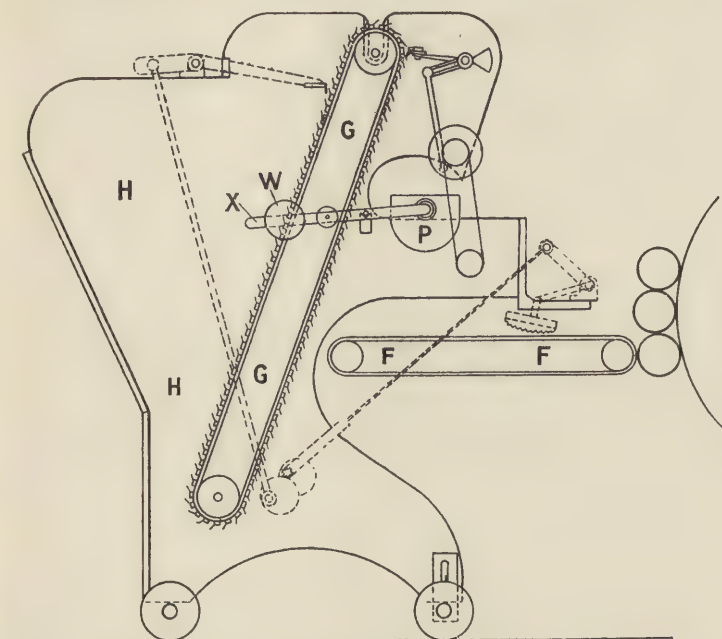


FIG. 65.—AUTOMATIC WEIGHING FEED PAN DISCHARGED BY OVERTURNING.

more wool than the other, and the sliver coming from the scribbler will be thicker on one side than on the other.

This would be an absolutely fatal defect where the simplest form of lap feed is used for the condenser card. No pains must be spared to see that the pan is uniformly filled along its entire length, but as the best machinery may fail at times

arrangements must be made between the various carding engines to obviate the results of any such possible irregularity (see "Intermediate Feeds").

As soon as the pan contains sufficient wool to raise the balance weight W on the lever X, a trigger is released that throws a clutch out of gear and stops the motion of the feed sheet G, until the pan has been opened by the lever L, which acts on two levers attached to the side of the pan for this special purpose. It now only remains to be noticed that the sheet G is driven from a fast-running belt through the clutch already mentioned, which makes its motion intermittent and subject to the control of pan lever X (see Fig. 66).

The pan is opened and shut by quite another agency. We talk of its opening "ever so often," say once in $4\frac{1}{2}$ minutes, but this is quite unimportant. It is not a question of time so much as it is a question of the movement of the feed sheet. The pan must give up its charge every time that the feed sheet F has moved a given number of inches, and therefore the motion that opens the pan through the lever L and the cam wheel C is driven positively from the feed sheet itself by means of a chain from the wheel 11 to that marked 13.

Put into mathematical terms this means that if the feed sheet roller is $2\frac{1}{4}$ inches diameter, the pan will open each time it has moved $8\frac{5}{4}$ inches, because $\frac{1}{11} \times 2\frac{1}{4} \times 3\frac{1}{7} = \frac{1}{11} \times \frac{9}{4} \times \frac{2}{7} = \frac{2}{28} = 8\frac{5}{4}$. The amount of material discharged by the pan every time it opens may be regulated to a nicety by the position of the weight W on the lever X.

This is the first of the many means by which the output of a card may be regulated. The speed of the feed sheet F and of the cam C may also be altered by the alteration of the wheels 28 and 25, and as this will reduce the amount

of wool going to the licker in at every revolution, it is quite clear that the weight coming off from the doffer will be relatively lighter in consequence.

The whole principle of this and of every other weighing-machine feed may be summed up by saying that the pan *P* must deposit exactly the same amount of wool on every section

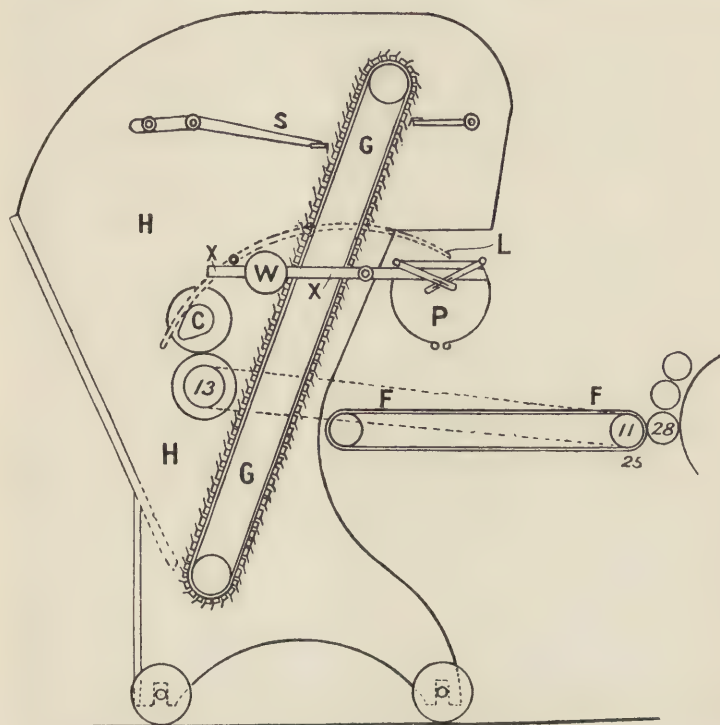


FIG. 66.—AUTOMATIC WEIGHING FEED.

of feed sheet. Or, in the words of an earlier writer, a given quantity must be made to occupy "a given space at uniform intervals of time."

Another machine constructed by English makers for a similar purpose is shown in Fig. 65. The manner in which

all these machines are connected with the card, the nature of the gearing and of the clutch, the shape of the hopper, and the method of discharging the pan, may all be slightly different from one another, but they, nevertheless, are successful in covering every section of the feed sheet with a uniform load of wool.

INTERMEDIATE FEEDS.—Before going into the details of the various methods by which carded materials from the scribbler are transferred to the feed sheet of the intermediate or condenser card, readers should do a little thinking on their own account. It is necessary that both practical men and students should consider carefully what is the principal object to be attained by the subdivision of a set of cards into three units of one cylinder each, instead of using a single machine, such as those used for shoddy, which have a breast and four “parts” in one long frame.

The reason is simple. If one of these long cards were fitted with a ring doffer or a tape condenser, and if by any accident more wool was placed on the right side of the feed sheet than on the left, the condensed threads from the right would be thicker or heavier than those on the left, and the resulting yarn would necessarily vary greatly in counts and strength. With so slight a variation as 10 per cent., counts that ought to be 22^s would only reel 20^s.

As has already been pointed out, automatic feeding has been designed with a view to remedying such defects; but carding engineers recognize that even the best machines are liable to make mistakes, and the various lap feeds and continuous feeds of various kinds have been designed to rectify any possible error that may occur.

1. **The Lap Feed** is far the simplest type of all, and

although it may be fairly efficacious in assisting to make a blend of colour uniform throughout a great length of yarn, it is the least efficacious of all the feeds in rectifying any difference in weight that there may be between the two opposite sides of a sliver.

Fig. 67 shows the lap machine in its simplest form. The thin film of sliver is removed from the doffer D by doffing comb C, and, still retaining its full width and fragile character,

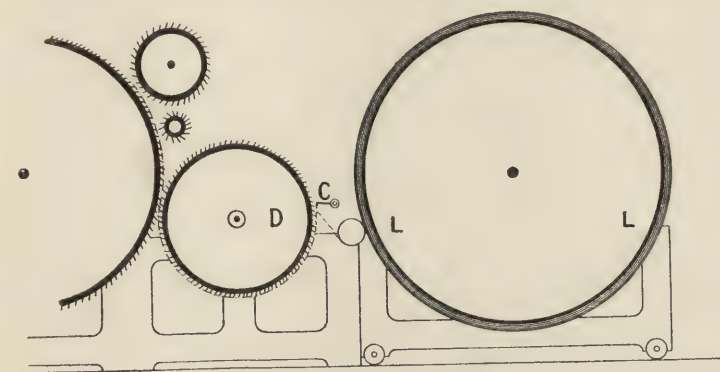


FIG. 67.—SIMPLE LAP FORMER.

is taken direct to the lap roller L, which may be 60 inches in diameter. Round this roller it is allowed to collect, or "lap," until the whole surface of the roller is covered with a dense and uniform mass of fibres. When the lap is of sufficient thickness, it is torn across in a direction parallel to the axis of the roller and taken to the condenser in the form of a sheet composed of, perhaps, 40 films, each $3\frac{1}{7} \times 60$ inches in length (or 188 inches long) and 60 inches wide. The fact that there are 40 films in the one lap makes the system very efficacious in mixing any variation in shade that may occur on the feed sheet; but by reason of its shape the lap must

of necessity be fed to the condenser in the same relative direction that it came from the scribbler, and therefore if the latter was fed more heavily on the right side than on the left, the two sides of the lap will differ in thickness, and the threads from one side of the condenser will be thicker than those from the other.

If, on the other hand, the lap be wound on to a roller that is only 60 inches in *circumference*, it may be fed to the scribbler with its fibres right across the feed sheet. This is better in theory, for it would not only produce a more bulky yarn, but it would obviate all chance of heavy weight on one side and light weight on the other. If more than one lap were fed at the same time on to the feed sheet of the condenser, there would also be an opportunity to average any possible inequality in weight; but if only one thick lap were used, another difficulty would arise. If there were any difference between the weight on the two sides of the lap, the heavy side would go up first, and yarn would come off heavy all across the condenser; but the weight would gradually decrease as the thin part passed the feed rollers, and all the yarn would be light in consequence.

All the simple lap machines are liable, at least in theory, to one or other of these two defects, and for this reason they are now seldom seen in this country. In the Martin lap former the lap is built on an endless lattice LLL of great length, arranged as shown in Fig. 68, but with the exception of increased length it does not differ from the method shown in Fig. 67.

2. **The Blamires Lap Feed** is probably the most efficient of all the apparatus now in use for blending colour and weight both longitudinally and transversely. In principle it is very

simple, but it is not an easy piece of apparatus to describe, and it should be seen to be thoroughly understood. Beyond the doffer of every card there is a travelling lattice 60 inches wide, exactly like the feed sheet, but 60 inches long (see A, Fig. 69). Its surface speed is exactly that of the doffer, and it carries the film that is removed by the doffing comb at full width. Under this sheet is another B of exactly the same dimensions which

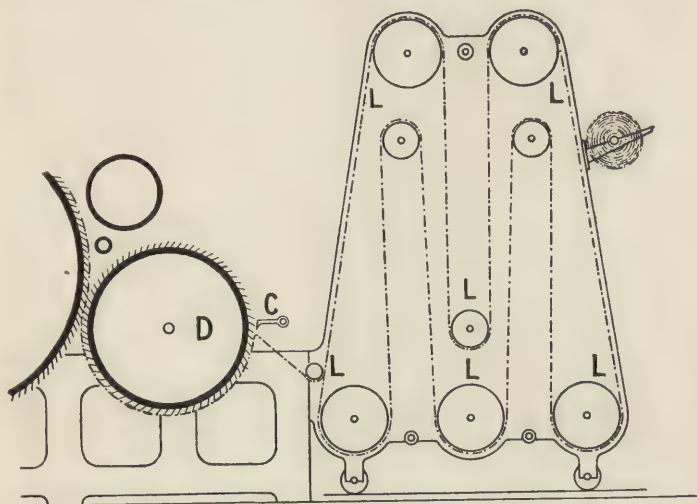


FIG. 68.—MARTIN LAP FORMER.

continually moves in a direction at right angles to the line of motion of the upper sheet. It is carried on a frame and rails, on which it not only rotates, but travels first 60 inches away from the card and then back again. The travelling carriage also holds the rollers R on which the lap is formed. By this means the thin film of wool is multiplied in thickness, and the direction of the fibre is altered before it is built into a roll of great length from which it will unwind. The result is practically perfect blending. If one side of the film is thicker than the other, the

thick side and the thin are both uniformly spread across the whole surface of the lap, which also goes to the condenser card with every fibre as nearly as possible across the feed sheet (see Fig. 70).

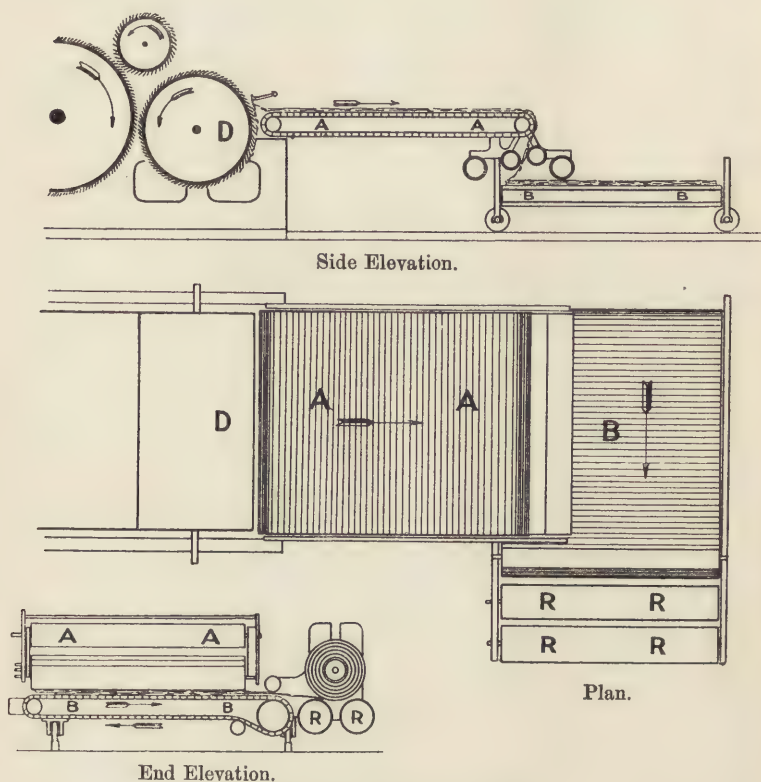


FIG. 69.—BLAMIRE'S LAP FEED.

The one disadvantage of this particular type is the great amount of room that it requires. It projects sideways beyond the shafts of the card, and in length cannot occupy less than twice the width of the lap, or 120 inches.

3. In the **Josephy System** a lap of similar type is formed with the fibres arranged transversely to its length. It is usually much

narrower in width and the space occupied in its formation is considerably less, but as it is not wide enough to go up direct to the feed sheet of the condenser card it must of necessity be

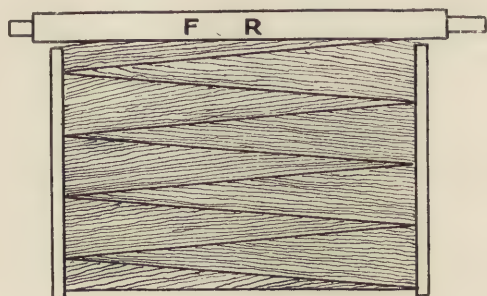


FIG. 70.—FEED ROLLER AND FEED SHEET WITH BLAMIRES LAP.

again arranged in layers across and across the width of the sheet in a kind of zig-zag pattern (see Fig. 71).

The whole of the carrying is done by belt conveyers or lattice creepers, and as this method effects a double crossing of the sliver, it is clear that the blending must be very uniform

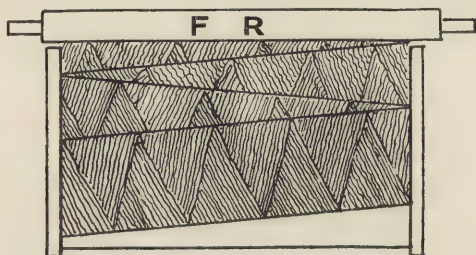


FIG. 71.—FEED ROLLERS AND FEED SHEET WITH JOSEPHY LAP.

both as to weight and shade, at all points across the width of the machine. If there are three units in a set of this description a similar apparatus is supplied between the intermediate and the condenser cards. In one essential it differs diametrically

from the Blamires feed. That machine arranges the fibres in the lap transversely to the length of the lap, but as this narrow lap from the Josephy machine is again fed transversely on to the feed sheet, all fibres really go to the feed rollers inclining to the same direction as that in which they came from the scribbler doffer (see Fig. 71). The tendency of this arrangement is to produce a smoother yarn with fewer ends of fibres

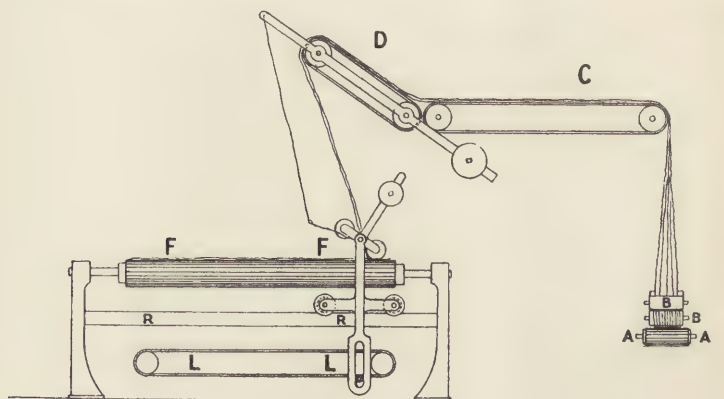


FIG. 72.—SCOTCH FEED.

- A. Lattice creeper of the Scribbler card.
 C, D. Carrying creepers.
 L.L. Motion which moves the distributing rollers too and fro on the feed sheet FF.
 RR. Rail on which the motion travels.

protruding, and users should consider whether this is desirable or not. It also has the great advantage of being entirely automatic. There is no breaking of laps and arranging them on a feed sheet, the work is quite continuous, and, with the exception of the formation of the lap, it has a strong resemblance to the Scotch feed. In the most modern machines the whole arrangement is exceedingly compact occupying less space than any other type (see Figs. 60, 61).

4. In the **Scotch Feed** the sliver differs from that of all the

foregoing machines in being much narrower. As the fibres are stripped from the doffer by the comb, they fall on to a narrow lattice creeper A and are drawn sideways to a pair of rollers, B, B at the side of the machine (see Fig. 72). Being delivered in the form of a sliver 4 or 5 inches wide with all fibres lying irregularly but for the most part parallel with its line of motion.

From this point the carded material is conveyed by lattice creeper to the feed sheet of the intermediate card FF where it is arranged in exactly the same way as in the Josephy system.

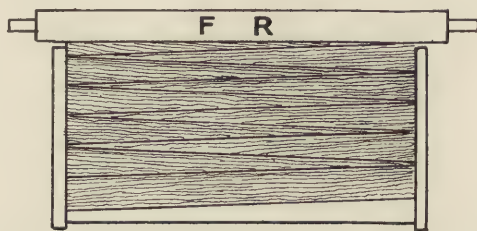


FIG. 73.—FEED ROLLER AND FEED SHEET FED BY SCOTCH FEED.

That is to say, it looks very much the same at first sight, but it differs because the fibres lie exactly across the feed sheet (see Fig. 73). The power of this machine to blend a sliver whose opposite sides were not alike in weight is as good as either of the foregoing machines, but it must be confessed that if a scribbler should happen to produce lighter weight than it should do for a space of two or three minutes the threads from the condenser would show more variation than in the case of any of the other types. Of course, with an automatic weighing feed this is well-nigh impossible, and it is fair to say that the Scotch feed is deservedly popular and in very general use.

The reader must remember the sliver is often composed of very short materials, and as there is no twist or any other agency to bind them all together, the sliver is very fragile, and

has to be used with the greatest care in consequence. For two reasons it has to be carried six feet or more above the floor.

First, because if it were not so there would be no passage between the two machines ; but

Second, because it can only be distributed evenly over the feed sheet from the long swinging lattice D of Fig. 72, which is always kept at a uniform distance from the distributing rollers by means of a cord attachment.

In order to get very fragile sliver up the upper lattice it has sometimes to be supported on both sides, and in consequence a double lattice would be necessary. If this were not so, a fragile sliver would break by reason of its own weight and total lack of tensile strength.

5. The Ball and Creel Feed is so simple as to need little explanation. The film from the doffer of the scribbler is formed into a rope or sliver by its passing through a funnel or other guide, on its way to an ordinary balling head, such as was common on all worsted cards, before the introduction of can feed to backwash machines. This balling head may be situated either opposite to the centre, or on one side (at right angles) to the doffer, as is most suitable to the arrangement of the machines. These balls are next arranged to a creel behind the intermediate card, so that the slivers should run up parallel, with all the fibres pointing to the rollers.

This system, which is seldom if ever used in this country, has the great advantage that any irregularity that occurred during the making of a whole set of balls would be entirely equalized in the intermediate machine. Fibres from both sides of the scribbler sliver would be found on all parts of the intermediate feed sheet. It offers opportunities for blending the output from the card at many different hours of the day,

and it ought to ensure a greater regularity of shade than any other system. But it has the great drawback that quite a large stock must be held between each pair of machines.

The number of ends that must go up to the feed sheet side by side would vary from 80 to 100. It would therefore be necessary to prepare eighty balls each weighing from 5 to 10 lbs. before the intermediate card could make a beginning. Few cards turn out more than 900 lbs. a day, as 80×5 (or 400 lbs.) may be taken as a minimum load for the creel, it is not difficult to calculate how much stock would be needed to each set, and how much time would elapse between the starting of the first machine and the completion of a set of rovings. Two days would be a moderate allowance of time, with nearly 1000 lbs. of stock, and it is not therefore surprising that makers who are obliged to handle lots of ridiculously small size, have never taken to this system, although at one time it was in use in America.

It is chiefly interesting as being a forerunner of the Apperley feed, but there is this important difference.

6. **The Apperley Feed** like the **Scotch Feed** is automatic and continuous, but it forms the fibres as they come from the doffer into a genuine sliver or round rope of fibres without twist. This rope is laid compactly and diagonally on the intermediate feed sheet with fibres that came from both sides of the scribbler in all sections of the feed sheet. It has a wonderful capacity for the blending, both as regards colour and weight, it is simple and effective in work, it is deservedly popular, and widely used. In order to save space the feed sheets are often made in sections of unequal length, and as all the fibres go diagonally to the feed rollers (see Fig. 74), the structure of the resulting yarn takes place somewhere between that of the plain lap and Scotch feeds.

We have now dealt with :—

1. The **Simple Lap Feed**, in which many films of wool as it comes at full width from the doffer are superimposed. They form a dense fleece of short length width which is fed by hand to the feed sheet of the intermediate card, with the fibres pointing to the feed rollers or across them.

2. The **Blamires Feed** in which a very long thick lap is formed of similar films, 60 inches wide, and is built into roll

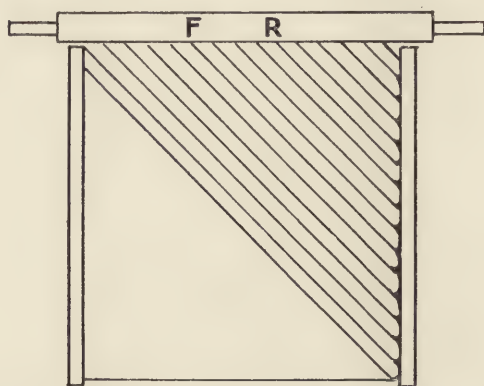


FIG. 74.—FEED ROLLER FEED SHEET. APPERLEY SYSTEM.

from which it may be unwound on to the feed sheet of the intermediate card, with fibres across the feed rollers.

3. The **Josephy Continuous Lap Former**, whereby a narrower lap is continuously laid across the feed sheet of the intermediate card by means of lattice conveyors, with fibres pointing direct to the feed rollers.

4. The **Scotch Continuous Feed**, which supplies to the feed sheet of the intermediate card a sliver 5 inches wide, laying that sliver across and across the feed sheet with fibres pointing across to the feed rollers.

5. The **Ball and Creel Feed** in which the fibres are laid

on the sheet with their points directed to the feed rollers; and

6. The **Apperley Feed** in which the film that is taken from the doffer, is also formed into a sliver, which is laid on the feed sheet with its length as well as with all the fibres diagonal to the feed rollers.

CONDENSERS.

The dictionary meaning of condensing is the act of packing or compressing a bulky article into rather less space than it previously occupied. The word originally applied in the trade solely to the rubbing or rolling of the open ribands of sliver that come from a ring doffer. In the old days, when doffers were clothed with sheets, the carded fibres came away in short lengths, exactly the width of the carding engine, and these strips were rolled and united into a continuous sliver by means of a piecing machine. So far as can be ascertained, a type of ring clothing was employed on doffers about 1820, but Bramwell said, in 1881, that "the makers of those rings never dreamed of doing anything further than still making cardings." He attributes the invention of the ring doffer to John Goulding, of Boston, Mass., in 1826.

By this means Goulding contrived to obtain the continuous delivery of a number of unbroken flat ribbons of sliver from the doffer of his machine, but he did not want the slivers flat, and so he invented a method for rolling them into compact round threads without twist; and he called this rolling or rubbing arrangement "a condenser." Properly speaking, a condenser card is one which has such a set of rubbing apparatus attached to it, and in practice the term is applied

to the last machine in every set, because that machine must have condenser leathers or rollers; whether it delivers its wool in the form of strips from a single ring doffer, or from double ring doffers. Rubbers are equally necessary when the wool comes from the doffer in the form of a single sheet the full width of the card, which is afterwards divided into a series of strips by what is called a "tape condenser."

In all these cases the condenser is the apparatus that rubs the flat ribbons of fibre into round thread-like "rovings."

These machines divide a wide film of carded wool into 80-120 narrow endless strips and should be called dividers. Celestin Martin, of Verviers (Belgium), was the first man to make them a success in practice, and he called them "continu."

Such a condenser may be made on either the model of Bolette's stationary steel-band divider; like the multiple-belt condenser with two or four pairs of condenser rubbers; or as a single belt "condenser."

It must be obvious to the least experienced critic that the amount of clothing on a "ring" doffer is nearly 25 per cent. less than in the case of a doffer that is uniformly covered with fillet, and it stands to reason the output of the ring doffer must necessarily be less in proportion. For the sake of simplicity, let us say that a machine, 60 inches wide, is clothed with rings, each of which is $\frac{3}{4}$ inch wide "on the wire," each of them standing $\frac{1}{4}$ inch from the nearest wire of the next ring. In this case it is clear that three-quarters of the doffer will be covered with wire points, whilst the spaces between them will be left vacant to prevent the entanglement of fibres on one ring with fibres on the ring next to it.

This method of clothing the last doffer of the condenser card was the first system of continuous production introduced,

and, in spite of all competition, it is still to be seen in the best card rooms in this country.

The Double Ring Doffer.—In order to obtain more carding surface, Americans very early on adopted the plan of using two doffers instead of one on each machine, each having half its surface only covered with card clothing. That is to say, each gap was equal in width to each ring of clothing; but the clothed portions of the upper doffer (see Fig. 75) corresponded with the gaps in the second or lower one, so that all the wool left on the swift opposite to the gaps in the upper doffer would be taken off by the rings of the lower one. Bramwell, who wrote

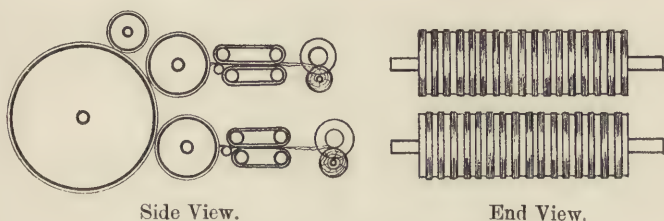


FIG. 75.—DOUBLE RING DOFFER.

at Massachusetts in 1881, says that the "two-doffer system is essentially American, and although it has been tried in every manufacturing country, it has invariably been abandoned and the single doffer used instead."

Even in his day it was well known that the produce of the top and bottom doffers was very apt to vary, and as he worked them himself, and was an exceedingly practical man, his verdict should be received with respect. He attributed the variation for the most part to the fancy, which "projected a varying quantity of fibres against the top doffer, which can in no case reach the bottom one."

To neutralize this tendency, the rings of the top doffer are always made narrower than those of the bottom one, but this

"is at most an unsatisfactory arrangement, for with one kind of wool a certain difference in width may be about right, but all wrong with another kind. A plan sometimes adopted, but very much opposed to good carding, was to set the top doffer further from the main cylinder than the bottom one. Even this failed to get over the different arrangement of fibres on the two doffers," and the dissimilarity of the threads coming from the two has prevented any general adoption of the double-doffer system even in America. We may therefore dismiss the system without further comment, though machines are still to be seen in use. The single ring doffer card is still extremely popular in many sections of the woollen trade in Yorkshire, in spite of the well-accepted fact that its output is ever so much less than that of a tape condenser. The work of the ring doffer is said to be better, because each ring or section forms a narrow sliver of its own, which has a definite natural edge; whereas it is claimed, with much show of reason, that when a wide film of interlaced fibres is cut up into strips by the action of the belts, long fibres must be cut or broken if the action is too much like that of scissors. If, on the other hand, the dividing edges do not fit accurately, long fibres are liable to be pulled from out of their proper place in one section, leaving thin places instead of a film of uniform density.

The enormous success of the tape divider on the Continent has, however, to be accounted for. It may be that the class of materials is a little better suited to this method of subdivision. There is not a shadow of doubt as to the cheapness and the increase of output, and it is well worth while, even at this late date, for Englishmen to consider if they could not capture a lot more of the lower grade trade by adopting continental methods.

The **Single Ring Doffer** is essentially an English institution; it has never been as popular in other countries, and, in spite of its limited productive power, it is being made and used to-day by the very best firms in the country.

No one who knows what a ring doffer is, can expect that it will compete in price with a tape condenser. A ring doffer 60 inches wide will produce 60 to 70 slivers $\frac{3}{4}$ inch in width, whilst the modern type of tape condenser will produce up to 120 half-inch slivers from the same width of machine. Each sliver is smaller, and the total weight is greater by 20 per cent. or thereabouts.

It seems to be a pretty well-established fact that in some trades in which we specialize, our foreign rivals seldom run us close. Take good old-fashioned West of England cloths as an example. On the other hand, our rivals beat us out and out on some types of cheap yarn. This may or may not be because we still adhere to old-fashioned machinery, content to have less output and do work somewhat resembling that our fathers did in milled and felted cloths.

Cotton, as is well known, will not stand spindle drafting more than 10 or, say, 15 per cent., and blends of cotton with shoddy or short wool (in which cotton preponderates) must not be drafted much more if the best results are desired. The shortest all-wool yarns, made up of various kinds of pulled materials, cannot be drafted very much more than cotton blends; but, on the other hand, the finest all-wool woollens, made from super P.P. grease, stand spindle draft carried to its extreme. Not only will they stand it, but practice proves that first-class yarn for super milling cloths can only be obtained by drafting thoroughly. The condensed thread for these two types must therefore be extremely different, to give the best results.

A yarn of 28-skein mungo and cotton is spun from 24-skein roving.

A yarn of 50-skein super Australian is spun from 18-skein roving.

In the first case the yarn is just $17\frac{1}{2}$ per cent. thinner than the roving.

In the second case the yarn is just 177 per cent. thinner than the roving. In other words, one yard of 24-skein mungo roving is extended by 16 per cent.; whereas one yard of pure wool 18-skein roving is extended by 1.80 per cent.

It stands to reason that two yarns, one of which is drafted ten times as much as another, cannot be alike in structure, but the writer has been unable to devise any microscopical arrangement that will show the difference between the sliver from a ring doffer and one from a section of a tape condenser; or between yarns produced with different drafts. Some people consider that free fibre ends (that is, ends that project from the surface of the thread) are a distinct advantage in a woollen thread. That is as yet unproven, but if it could be stated as a fact it would be a strong argument in favour of tape condensers, for the sections that come from a fillet-covered doffer which are severed into ribbons by the actions of the tapes, must of necessity show more free fibre ends than a complete, if narrow, sliver coming from a single ring. Such a sliver, as already argued, must have edges with a formation that may be compared with the selvage of a piece.

To the novice it will doubtless appear unlikely that the various rings will be covered with an equal density of fibres. The first roller card that was ever made had an arrangement for moving alternate cylinders to and fro horizontally, in order to effect the spreading, which the inventor expected would be

necessary. We know now that any such movement is quite superfluous, because the great difference that exists in the speed of workers, swifts, and doffers, helps to blend fibres that go through the feed rollers at quite appreciable intervals of time.

How little fibres move laterally is amply proved by the fact that few fibres work off the sides of the machine. It is only natural to expect that the wool would spread wider on each succeeding roller, but this never seems to be the case. Bramwell states his belief that all fancys tend to throw the wool into the centre of the machine, and this is confirmed by the fact that the edges are always irregular. So much is this the case that the two outside (edge) slivers are never considered fit for spinning. They do not take their place on the spool, but are run off on to separate balls, and again taken back to the feed sheet of the condenser card to be worked up afresh. Excepting these two threads, the output is wonderfully regular, and it is only necessary to consider the means by which the flat ribbons are removed from the rings and condensed into roving.

The doffing knife which is used on all fillet-covered doffers is seldom, if ever, applied where rings are used.

The numerous slivers are drawn from the wire by rollers, and transferred by them to the condenser rubbers. All rubbers are very much alike. They are wide belts or aprons of leather stretched tightly over rollers (see Fig. 76) that have two motions. The upper surface of the under leather and the under surface of the upper one are continually moving away from the doffer at a pace that is just in excess of the output of the doffer. They carry away between them the delicate films of fibre, but at the same time they move rapidly to and fro, one to the right, whilst the other moves to the left. The consequence is that

the fibres are rolled or condensed into a round roving resembling a thread, but having no tensile strength because it has no twist. The means by which the rocking motion is imparted to the roller shaft is different in almost every make of cards, but in principle there is so little difference that almost any one of them might be taken as typical of all others.

Because the distance and speed that the two contiguous leathers move in opposite directions is exactly the same, the thread is rolled without moving sideways to any appreciable extent, but as there is only a gap of $\frac{1}{4}$ inch (or less) between

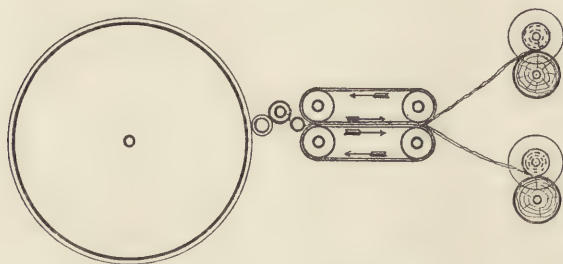


FIG. 76.—SINGLE RUBBER CONDENSER.

the edge of the various slivers as they come from the doffer, some makers and users consider that there is a danger of their being entangled in the rubbing process. Some people also consider it an advantage to extend the sliver in length (and therefore reduce it in size) before it reaches the spool, and these two opinions are the cause of all the variations that are seen in the condensers that are applied to ring doffers.

1. The **single rubber condenser** has only one pair of leathers through which all the slivers go side by side and very near together, one to every inch of width. In this system the condensed thread is very little lighter than the uncondensed sliver as it comes from the doffer (see Fig. 76).

2. The **double rubber condenser**, with two pair of leathers, one above the other, has a clear advantage for all long fibred qualities. All the odd slivers go to the upper pair of rubbers (Fig. 77), the even numbers going to the lower ones. This

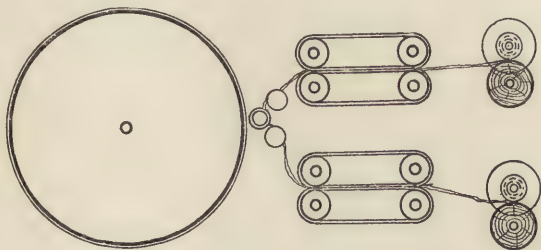


FIG. 77.—DOUBLE RUBBER CONDENSER.

means that there is more than double the space between the outer fibres of any two contiguous threads, with greatly reduced chances of entanglement.

3. **Tandem condensers** (Fig. 78) are applied to give a certain amount of draft or extension to the various threads. If the

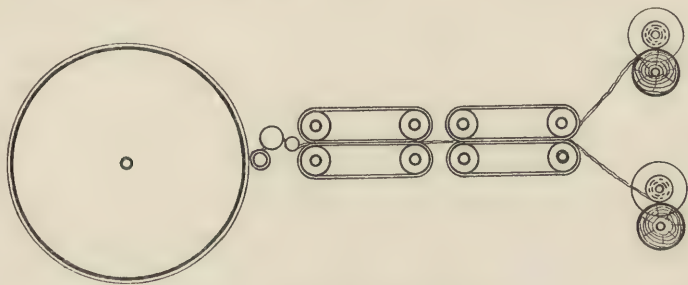


FIG. 78.—TANDEM CONDENSER.

doffer gives up 8 inches per second, and if the first pair of rubbers travel at a speed of 9 inches per second, material that was coming from the doffer at a weight of 16 skeins would weigh 18 on the spool, and if a tandem rubber is introduced

travelling with a speed of 10 inches the length will be increased and the weight reduced to 20 skeins.

There is another point that deserves a moment's notice. As about 60 threads come from a doffer 60 inches wide, there would be twice too many threads on every spool for a mule of 2 inches pitch, unless half of the threads were taken to an upper spool and half to a lower; when all are going through a single condenser (Fig. 76) or single tandem, as in Fig. 78. This principle is carried still further in all tape condensers. They produce up to one sliver from every $\frac{3}{8}$ inch of doffer

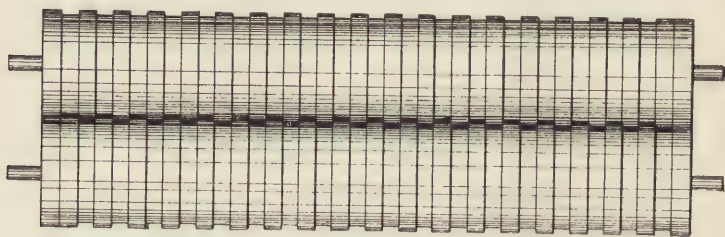


FIG. 79.—DIVIDING ROLLERS.

surface, and, therefore it is necessary in that case, to build the roving that is condensed from every doffer on to four separate spools. Sometimes four rubbing systems are employed, more often only two, as in Fig. 80.

Tape condensers or "**dividers**" are really machines for shearing or dividing the film of carded fibres that comes from a fillet-covered doffer. If the doffer is 60 inches on the wire the condenser may shear it into 120 or even 160 narrow continuous ribbons, each of which is then condensed or rubbed into a round form and wound on to a spool or bobbin. The essential part of the machine is the pair of square grooved rollers (Fig. 79) in which the rings of the upper cylinder run exactly opposite to the groove in the lower one, and *vice versa*.

In each groove a belt is running, and as each alternate belt (whilst steadily running forward) crosses the course of the next, as is shown in Fig. 80, the two act exactly like a pair of scissors that are continually closing. They really clip or sever the wide sliver into as many endless strips as there are grooves in the two rollers.

One of the first of this type of machines to become a commercial success was known as the **Bolette** machine, but it was not a belt condenser properly so called. In it the fibres were divided by a pair of steel springs, which occupied exactly the same position as the belts shown in Fig. 80, but they did not "run" like the belts that are now so common. They were practically stationary, half of them attached to an upper roller and half to a lower roller. These rollers have a very slow reciprocating motion, which has no part in the shearing action, but continually alters the position of the steel bands to such an extent that the part at the point of intersection is always changing. This keeps the cutting surface always clean, and prevents the accumulation of waste at the point of intersection. It is quite clear that with the knives stationary, the wool must be moved along by the endless leather belts or aprons against the slight friction of the polished spring knives until the fibres reach the end of the knives. When they reach that point they are flat and very incoherent films of fibre, exactly like the product of the ring doffer, but the moment they leave the knife they come under the influence of the rubbing or condensing leathers. The purpose of the rollers is simply to apply pressure on the knives, and hold them tight against the leather tapes.

This machine became a standard type upon the Continent but in this country it has never taken root, for almost all the

tape condensers that we have in work have leather dividing bands.

Leaving out of account all dividers with metal bands, tape condensers are divided into two great classes—

1. Those that have a separate belt for each pair of grooves in the rollers (see Fig. 80).

2. Those that have one very long belt which goes consecutively through each groove in turn, and finally returns from one side of the machine to the other, to begin its work again (see Fig. 82).

In theory both kinds are exactly alike, and depend upon the intersection of the belts in the “nip” of the rollers, where each different belt, or different part of the same belt leaves the groove in the low roller for a ring on the upper roller, and *vice versâ*, gripping its own ribbon of fibres between itself and the ring. This very complicated arrangement is almost impossible to depict clearly by diagram, and every one who wishes to understand the tape condenser is strongly recommended to see one at its work. In all tape condensers the rollers are the essential part of the dividing machinery, all other parts being either condenser rubbers, or such an arrangement of the dividing belts as will convey their strip of sliver to the right pair of rubbers without strain or disturbance.

Though Celestin Martin was not the first man to make a tape condenser, it was he who introduced the twisted belts that are now so general. The first object of twist in the belt was to invert. All the tapes that hold the wool against the upper roller after they are through the nip have the film of wool on their upper surfaces as they support it all the way to the rubbers, but the tapes that go downwards have the film on their under side.

If the distance from the grooved dividing roller to the condensing rubbers is considerable, there is a tendency for the fibres to fall from the carrying belt and run to waste, unless the staple of the material is pretty good.

Multiple Belt Condenser.—The usual arrangement of belts

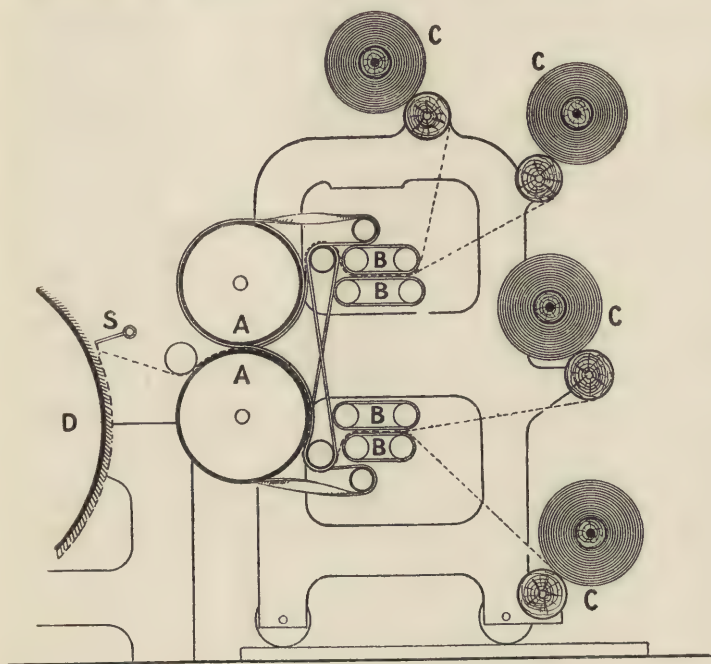


FIG. 80.—MULTIPLE BELT CONDENSER.

D. Fillet-covered doffer.
S. Stripping comb.
A. Dividing rollers.

B. Rubbing leathers.
C. Spools of roving.

in these machines looks very complicated (see Fig. 80) when both upper and lower belts are in position, but when only one is shown, as in Fig. 81, it is obvious that the simplest possible method has been adopted which will take the belt as low as necessary, and return it to its old place on the upper roller. When a new machine of this type begins to work, the

belts are all cut so exactly to one length and size, that all of them exert exactly the same pressure. They consequently produce slivers of exactly similar weight or size; but the density and strength of leather is always apt to vary, and after

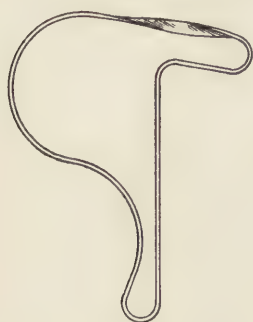


FIG. 81.—COURSE OF A SINGLE CONDENSER TAPE.

a little use, some of the numerous belts contract in sectional area a little more than others. The tighter belts will always rob the slacker ones of some portion of their proper load, and the condensed threads will consequently vary in weight. Obviously a single tension pulley extending the whole width of the machine can never put equal pressure on belts of different

weights. The only way to obviate this trouble would be to put a separate tension pulley to every belt, so that each could be regulated to suit its own requirements. This would so greatly complicate the mechanism and increase the trouble of management, that it is never attempted in practice, and though multiple belt condensers are still far from uncommon they are rapidly being ousted by the simpler machine.

The Single Belt Condenser.—In this type of divider the rollers are grooved as in Fig. 79, but instead of having a separate short belt for every different groove, a single endless belt of 200 yards or more in length begins work at one end, and, after describing as many figures of 8 as there are grooves in either roller, it reaches the farther side of the machine, and is carried back over the tension pulleys to the place from which it started. It is clear that the tension of every part will soon be equalized, and the size of the condensed threads will be accurate in consequence; but, on the

other hand, the wear and tear are considerably increased, and the life of the belt is naturally shorter.

The difference of the density in different parts of this long belt will naturally cause it to vary slightly in size and thickness in different parts of its great length, but the force

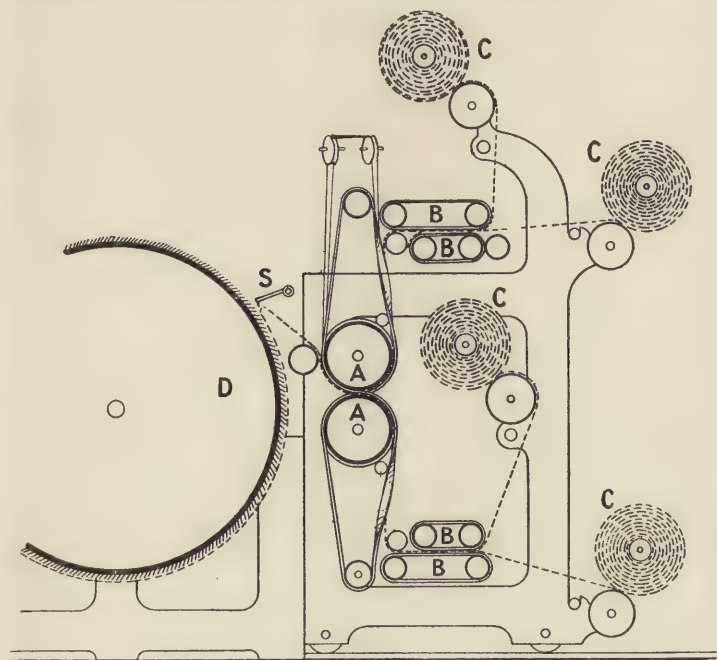


FIG. 82.—SINGLE BELT CONDENSER.

D. Fillet-covered doffer.
S. Stripping comb.
A. Dividing rollers.

B. Rubbing leathers.
C. Roving spools.

with which it grips the fibre is much more important than the width to the fraction of an inch of the gripping surface, and it seems a well-accepted fact that the advantages of this system greatly outweigh the drawbacks, and the shorter life of the single belt.

As only 30 ends are required on a spool which is 60

inches in length (to supply one condensed thread to every spindle of a 2-inch pitch mule), it is clear that if there are 120 half-inch dividing belts in the condenser there must be four spools made from the output of the doffer. The fact that half the ends are carried down, whilst the alternate ones are carried upwards from the nip, makes it natural to expect two sets of rubbing leathers, as shown in Fig. 82. In that case each pair will deal with 60 ends; there will be one to every inch of rubber surface. As they enter, there will be half an inch of open fibres, and half an inch of space between each and the next. For short materials this is quite enough, but in the case of longer stapled sorts the fibres will project across this space, and will become entangled with adjacent threads. This will make both of them uneven, if it does not mean the complete amalgamation of the two in one quite useless roll, particularly if the belts have a long side stroke.

When there is any chance of such things happening, four sets of rubbers should be used, as in Fig. 61. Each of them will then only have to deal with 30 half-inch slivers, one in every two inches of their length, and instead of the threads from one pair of rubbers going on to two distinct spools each pair now have their spool.

Rubbing or Condensing Proper.—Those who know anything of drafting on the mule must all be well aware that rubbing has a very potent bearing on that process. Each sliver must have just sufficient rubbing to make it round and strong enough to wind on to the spool; but, on the other hand, if rubbing is too hard for any sort, the fibres set too quickly when the twist is put in; so that the fibres draw unevenly. The rubbers must be set for various sorts as is

expedient—no rules can be laid down. Here, as in so many other places in this trade, slight differences in the setting of various parts may give extremely different results. This book does not deal with practice, but with principles, but from Figs. 80 and 82 the least expert can see that both have not been built to do the same kind of work; one, for example, is for stronger sorts. It gives the sliver no support between the doffers and the roller. Sometimes the belts are so arranged that they support the tender sliver of much shorter fibre so that it will not break in this short journey, and as the shorter fibre needs more rubbing to ensure the needful strength, each pair of rubbers may work on three instead of on two rollers.

Sometimes both leathers may be made one length, sometimes the upper or the lower one is shorter than its fellow. Such an arrangement may be made to give great latitude in pressure. To sum up in one sentence, we may say the tape condenser must be understood to be of any use. When it is understood, it must receive more credit than is yet the case in England. The writer is not one who thinks that it will altogether oust its older English rivals in every trade. That is no reason why it should not play its part, and play it to advantage in more ways than one.

CHAPTER X

THE MULE

ATTENTION has already been drawn to the personal element that shows so prominently in other processes of the woollen trade. In rag grinding and in carding continual oversight is absolutely necessary to obtain the best results. Nevertheless one can conceive of a lot of new material being put through a set of carding machinery, adjusted for some other type of wool, without there being actual disaster. In the mule, on the other hand, the necessity for judgment based on long experience is necessary for every separate lot. It is difficult to imagine how a new quality or count could be started without the special and personal attention of some one in authority. And when the woollen mule is compared with its prototype in the cotton or in the worsted trade, it only increases the impression that personality is all-important.

In cotton and worsted mules, the extension of the thread is almost wholly due to the roller draft, which can be calculated with extreme nicety, without reference to any other factor. In woollen, on the contrary, carriage draft is the only means of extension; but carriage draft must be applied at the right time, in regard to the speed of spindles and to the twist that they insert, and also with due regard to the nature of the material in hand.

In theory, the woollen mule is one of the simplest of machines, for the parts that actually treat the wool are only two in number—

1. The rollers R, that pay out the roving from the condenser spool C.

2. The spindles S, that move to and from the rollers in the carriage K at the same time that they rotate on their own axes. The spindles have three entirely different functions to perform—

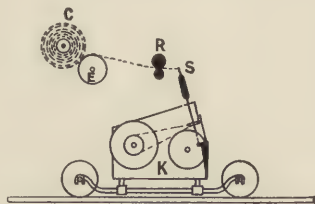


FIG. 83.

1. As they move away from the rollers they extend the roving by 5 per cent., 10 per cent., 50 per cent., or even 100 per cent., of its original length.

2. At the same time they insert twist.

3. And afterwards wind the yarn on to cops built upon the spindles by the direction of the guide wires.

Theory is, however, one thing and practice is quite another. The mechanism that is necessary to give the requisite motion to the spindles and the rollers is of the most complicated description. It would be far less complicated if the motion of the spindles and of the rollers were continuous, but this is not the case. Comparatively speaking, the motion of the rollers is simple, for they always rotate at the same speed when they are moving at all. It is their business to pay out a given length of condensed thread, and then remain stationary until the spindles have extended it to the required length, put in the twist, wound it on to the cop, and returned to their first position, with their tips 2 inches from the rollers. On the other hand, the movements by which the spindles effect these

results are extraordinarily intricate. The more one knows about a mule, the more one wonders that its inventors ever succeeded in making it work.

The spindles have no less than ten different motions. As forming part of the carriage they—

1. Move away from the rollers whilst they are delivering roving, and continue to do so until the rollers stop.

2. They continue to retreat from the rollers at a slower speed, until the carriage reaches the end of the stretch.

3. Whilst twist is being inserted, they are first stationary, but finally move in a few inches towards the rollers, because the increased twist reduces the length of the yarn, and the tension would be too great if they remained at the extremity of the traverse.

4. The carriage again remains stationary whilst the spindles unwind a few inches of thread.

5. The spindles and the carriage return to the rollers, during the winding of the yarn on to the cop, at speeds that continually alter during the journey.

In rotation their motions are still more intricate.

1. Whilst the roving is being paid out, they must put in just enough twist to make the fibres “set” to the desired extent. Too many revolutions, or too few, are equally fatal to perfect drafting.

2. They continue to revolve at the same speed throughout the drafting or extension of the yarn, until the carriage reaches the end of the traverse, when the drafting is complete.

3. When the drafting ceases there is no further need to limit the speed at which the spindles revolve. In order to get in the requisite number of turns per inch, in the least possible

time, they therefore rotate at a greatly increased speed, whilst the carriage, as already stated, moves in a few inches to ease the tension caused by increasing twist.

4. They stop, and rotate about six turns very slowly, to pay out about 1 foot of yarn, that is wrapped round the spindle above the cop. This goes on whilst the guide wires take up a position suitable for winding on to the cop the stretch of yarn that has been spun.

5. As the carriage runs in again towards the rollers, the spindles rotate very slowly at an ever-varying speed. It is a speed so complicated that the surface traverse of various portions of the cop coincides exactly with the speed of the carriage as it runs in towards the rollers. If the spindle speed were too small the yarn would be too loose to build a satisfactory cop, and if it were too great, the yarn would be stretched or broken. To get some idea of the intricacy of this motion, it must be borne in mind—

1. That the yarn is being wound on to parts of the cop that continually vary in size.

2. That the speed of the carriage is not uniform.

3. That the movement of the traverse wires requires more slack yarn at the beginning than at the end of the run in.

If a clever modern mechanic unacquainted with the trade were asked to supply such a motion as this, he would probably reply that it would be utterly impossible to transmit it with sufficient accuracy by anything but a positive drive. This is so far true, that the more one understands of the difficulties which are involved, the more wonderful does the action of the mule become.

FIRST STAGE—PAYING OUT.

1. Rollers (R) revolving.
2. Carriage (K) running out.
3. Spindles (S) revolving slow speed to the right.
4. Faller wire (F) out of action above the threads.
5. Counter faller wire (C) out of action below the threads.

It would, of course, be possible to write a description of a mule headstock that would be technically correct; but from his own experience, the writer feels that such a description

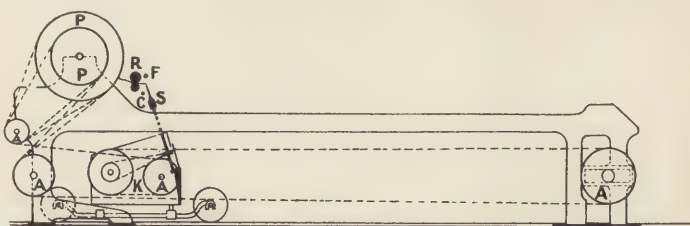


FIG. 84.

would be so intricate as to be entirely valueless to the average reader. The plan has, therefore, been adopted of discussing each of the foregoing movements, first in regard to its theory of work, and afterwards in regard to the mechanism that actuates it. The movement of the carriage, the spindles, and various other parts of the machine are, however, so intimately associated with one another, that it is impossible to consider them separately. It is for this reason that the motions of the carriage have been numbered to correspond with the various spindle speeds.

In Fig. 84, the carriage and the spindles are shown in the position in which they stand with regard to the rollers when the spinning process commences. The low roller and the press

roller R deliver to the spindles S the roving, which is paid out from the spool as it is rotated by the carrying roller, the surface traverse of which is exactly equal to that of the rollers R. By this means the twistless roving is delivered to the spindles without any tension being applied to it. At the same time, the carriage K and the spindles S move away from the rollers at a speed so near to that of the rollers, that the roving remains under slight tension without being extended. But the spindles rotate at a speed that will insert just sufficient twist to make the roving suitable for drafting. The number of turns per inch which is necessary, will differ with every different blend of materials, and nothing but a long practical experience, and a very complete grasp of the theories involved, will enable a spinner to adjust a mule properly for this, the most important part of its work.

If a novice is desirous of understanding the subject thoroughly, by far the best thing he can do is to learn how to use a hand spinning wheel. In hand spinning there is no drafting but that between the spindle tip and the fingers. A beginner will, therefore, very quickly learn the only way to obtain an evenly drafted thread. He will find that it is essential to allow the correct amount of twist to escape through the fingers of the hand nearest to the spindle into that portion of the sliver where the drafting is to be done. If too much twist is allowed to pass, the fibres are bound so tightly together that they will break or "pluck," rather than draw evenly. On the other hand, if too little twist is used, the sliver is so soft that the fibres will come away in lumps from the distaff and so form a very uneven yarn; if it does not break down altogether.

Now exactly the same thing will happen in the mule. If any attempt were made to draft the twistless roving, by moving

the spindles away from the rollers at a greater speed than the rollers were delivering the roving, without putting in some twist, the roving would infallibly break. On the contrary, if a yarn of 40 skeins, with 20 turns per inch, is to be made from roving condensed to 20 skeins, the rollers must clearly pay out 36 inches every time that the spindles make a traverse or draw of 72 inches. In that time the spindles would have to rotate 3600 times, or 20 revolutions for every inch that they move away. This means, that when the spindles are 2 inches away from the rollers they will have put 40 turns into the 2 inches of yarn, and it needs no argument to prove that any drafting would be utterly impossible with so much twist present. The fibres would be so tightly bound to one another that no motion between them would be possible. It would therefore be quite impossible to extend the yarn, and it would infallibly break in two. This makes it abundantly clear that the spindles must run at one speed whilst the roving is being paid out, and that the requisite number of turns must be made up **after drafting is complete.**

The difficulty is to decide how much twist must be put into the roving before drafting begins, and the problem is complicated by the fact that every different quality, as well as every different length of material, will "set," with a different number of turns per inch.

Experience with a spinning wheel will be of no small service in helping a man to decide what twists to use. The hand spinner will know that long English wools can be drafted with very little twist indeed. As fibres get shorter the twist they require will steadily increase if the quality, or diameter, of hair remains the same. A 4-inch merino will require less twist than a lower quality of equal length. And a fine mungo

may require more than double the amount that is suitable for the merino, although the diameter of the fibres is probably equal.

In other words, the twist required will vary in some indefinite relation to the length of the fibres, and the number of them that go to make up a roving of any given weight. In a condensed roving of any weight, before it is twisted, the various fibres lie so loosely against one another that they can move with practically no friction, and the result is that the roving has no tensile strength whatever. It will break rather than draw or draft.

In hard twisted yarn of the same number of skeins, the same number of fibres are pressed by the twist so tightly against one another, or wrapped so tightly round one another, that they will break rather than move on one other.

It is the business of every man who has mules under his care to know exactly what is the happy mean between these two extremes. Every different length and quality of material has its own particular mean, and it is therefore far from being an easy matter to decide what amount of twist to insert.

We will suppose, for the sake of argument, that a 20-skein roving of pure wool is to be drafted to 40-skein yarn, and that it will require 4 turns per inch to make it set sufficiently to draft well.

If the delivery of the rollers and the speed of the carriage is 520 inches per minute, 36 inches will be delivered in 4 seconds, and if 4 turns are to be put into every inch the spindles must run on their first speed of 1920 revolutions per minute to get in the necessary number of turns before the 36 inches of roving is paid out and the rollers stop.

SECOND STAGE—DRAFTING.

1. Rollers (R) standing.
2. Carriage (K) continues to run out slowly.
3. Spindles (S) continue to revolve at the same speed to the right.
4. Faller wire (F) out of action above the threads.
5. Counter faller wire (C) out of action below the threads.

It is during this section of the run of the carriage that the greatest knowledge is required, if the best possible results are

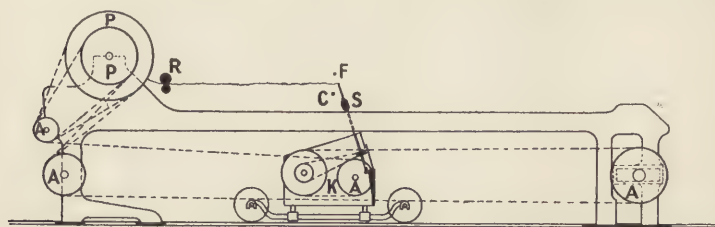


FIG. 85.

to be attained. The theories involved are extremely complex, and require close attention. The beginner would naturally imagine that when the requisite length of roving has been delivered and the rollers stopped, the spindles would also remain standing whilst the continued movement of the carriage would extend the yarn from 36 inches to 72 inches in length. It seems reasonable to conclude that if the spindles continue running, the yarn would become too hard after slight extension had taken place.

Practice, of course, proves that this is *not* the case, and it is also clearly provable by theory. In the first place, if 36 inches of roving containing 144 turns, or 4 turns per inch is extended to 48 inches, each inch will only contain $1\frac{4}{8}$, or,

3 turns, with a more than equivalent reduction in the pressure or the friction of the fibres on one another.

In the second place, it is well known that to obtain equivalent strength in a 20-skein thread and one of 27 skeins, the twist in the finer one must be largely increased; and therefore, instead of standing, the spindles have to go on running to supply the turns that are needed for the two reasons given above.

Some theorists say that equivalent strength will be obtained by keeping the pitch of the twist in constant relation to the axis of the thread, which is about equivalent to making the number of turns proportionate to the diameter. Others are inclined to put the ratio more nearly inversely to the square of the counts. In this case theorizing is of no use whatever. It is, nevertheless, certain that the twist must increase as the carriage runs out, and it must increase so fast that the carriage generally moves over the second half of the traverse at a suitably slower rate than over the first half. At the same time the spindles continue to revolve as before, in order to keep the necessary tensile strength in the attenuated roving or thread.

Let us say that the speed of the carriage is halved whilst the speed of the spindles remains the same until the extremity of the traverse is reached. This means that the second 36 inches of the traverse will occupy 8 seconds, and that the spindles will put in $\frac{8}{60}$ of 1920, or 256 additional turns, before drafting ceases. The counts will then be 40 skeins, the 72 inches of yarn will contain $144 + 256$ turns, or $4\frac{0}{7}\frac{0}{2}$ per inch. This is $5\frac{1}{2}$ turns per inch. But if there are to be 25 turns per inch throughout the whole length of the 72 inches, 1800 turns will be required altogether, and the spindles will

therefore have still to put in 1400 turns before the yarn is hard enough for use.

To do this in the shortest possible time, the spindles will at once increase in speed until they are revolving at 3120 revolutions per minute. At this speed it will take them 24 seconds to put in the additional 1400 turns, which will be necessary to add $19\frac{1}{2}$ turns to each inch of the 72.

Worsted spinners who are only acquainted with roller draft, have an axiom regarding the ratch. They say that the rollers between which extension takes place must be very little further apart than the length of the longest fibres in the material under treatment. When they hear that woollen spinners can draft a mixture of cotton and shoddy between the rollers and spindle, that is, 40 inches distant from it—they jump to the conclusion that the resulting yarn must be frightfully uneven and lumpy. They leave out of account altogether the effect that the twist has upon the fibres, and it is to be feared that some of the less scientific of the woollen spinners also fail to grasp the full use that may be made of twist.

An experienced hand spinner will not make this mistake, but will know quite well that if he should produce a slightly uneven yarn (*i.e.* one with thicker or thin places in it), it is possible to make that yarn practically perfect, by simply extending it to a greater length between the fingers and the spindle tip. It is only necessary to have the right amount of twist in the thread, and then to draw it gently but firmly from both extremities. The result is curious. A novice would expect that the yarn would break at the thin places. The exact opposite is the case in practice. For purely mathematical reasons, which are too abstruse for discussion here, the twist runs into the thin places first. This is easy to see, and

it is also well known to be a fact. The result is that the thin places are the strongest, because the fibres are bound tightly against one another, and consequently the thick places give way and are extended because they contain less twist, and because their fibres are not pressed so tightly together as the fibres in the thinner part. The two following facts may therefore be stated as laws, to which there is no exception:—

1. Any length of thread that receives twist at one extremity will not have the turns distributed quite uniformly over its entire length, but will contain more twist in the thin than in the thicker places.

2. If the yarn does not contain so much twist as to prevent all draft, and if it is held by its two extremities and extended, it will give way in the thicker or softer places, until they are so thin as to attract and absorb twist from portions that are thinner and contain more twist.

These two laws underlie all carriage draft, and the practical man must not only believe in them as laws, but must understand how to take advantage of all the possibilities that they offer to him in making a perfect yarn.

Incidentally, it is well worthy of notice that the nature of the material and the percentage of the draft will greatly affect the output of the mule.

Short material will require more turns to obtain a given strength. For example, a fine mungo yarn of 15 skeins with 20 turns will be no stronger than a puro merino yarn with 5 turns less per inch. Therefore the mule will obviously do 20 pounds of merino in a great deal less time than it will need to spin the same amount of mungo.

In addition to this, there is a less obvious cause of difference. With a quality that will stand a draft of 50 per cent., a less

amount of twist is necessary during the time when the spindles are running on the slower speed, whilst the carriage is moving out. The carriage will therefore be moving faster, and the spindles will be running at the highest speed for a greater percentage of their time, whilst the larger of the two rim pulleys is driving the spindles.

Before leaving the second stage, there is one more theory that deserves attention. Every one knows that the spindles

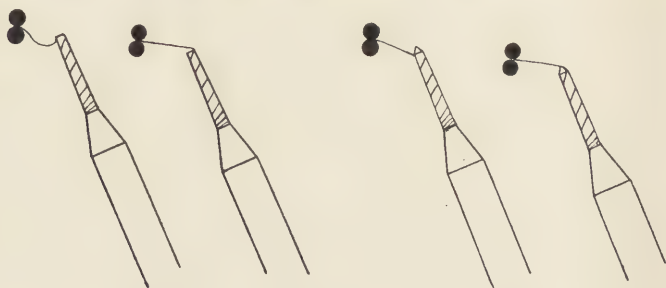


FIG. 86.

FIG. 87.

FIG. 88.

FIG. 89.

of a woollen mule do not terminate in a point, but are square-ended. This practice is so universal that few people appear to notice that square-ended spindles are not employed in any other trade. In cotton and in worsted mules, when carriage draft is subsidiary to roller draft, the spindles end in a point. Any one brought up in either of these two trades cannot fail to notice the difference when he first sees a woollen mule at work, but it appears that few people inquire the reason. It is said that pointed spindles (see Fig. 88) have been tried, and found to give inferior results to those that are obtained from square-ended spindles in the production of woollen yarns. If this be so, it seems quite clear that the square-ended spindles must give a series of jerks to the yarn that facilitate the drafting process.

When the yarn is wound round the spindle in a spiral form, as in Fig. 87, there must come a time in every revolution of the spindle when it is in the position there shown, whilst it is equally clear that, half a revolution later, the thread must have fallen over the nose of the spindle and taken up the position shown in Fig. 86. It is equally obvious that the jerking which will result from this process must be much less if the spindle terminates in a fine or cotton spindle point. And it is therefore suggested that this type of woollen spindle is the result of natural or mechanical selection, arrived at by practical men, who may or may not have based their practice on the assumptions that are here offered as a solution of the problem.

THIRD STAGE—COMPLETING THE INSERTION OF TWIST.

1. Rollers (R) standing.
2. Carriage (K) standing or drawing slightly in towards the rollers.
3. Spindles (S) running at top speed to the right.
4. Faller wire (F) out of action above the threads.

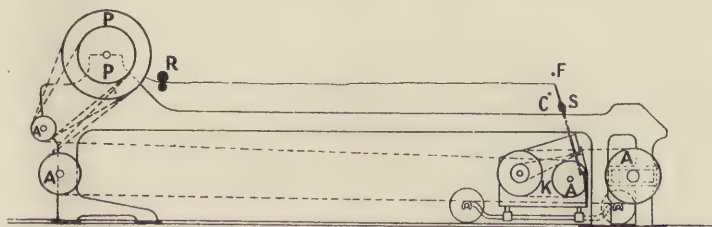


FIG. 90.

5. Counter faller wire (C) out of action below the threads.
- This stage, already referred to, is a period in which the

rollers of the mule are stationary, and during which no drafting is going on. It is, therefore, a time in which the mule is quite unproductive, and for this reason it should be reduced to the least possible duration. In practice it is invariably made as brief as possible, for in all mules the spindles at this stage are driven by the large rim pulley, and run at their maximum speed, which varies from double to five-thirds of the speed at which they rotate while the rollers are paying out the roving.

Apart from the saving which is effected by putting in the greatest possible number of turns in the least possible time, there is only one theoretical consideration that needs attention. It refers to the contraction of the yarn due to the insertion of twist. It is well known that if 16 turns per inch are put into a 2/40 worsted in the folding process, it will so far reduce the length of the two single strands that form the twofold thread, that these must be spun to 42 to give a finished thread of 2/40 actual counts.

It is obvious that if the two threads were spun to 42^s and simply wound side by side on to the bobbin, they would continue to reel 2/42 in that condition, and it seems equally obvious that the more times these two strands are wrapped round one another the less distance will they extend in a straight line. Clearly, also, the shorter they are in the finished state the greater will be their weight per yard. Exactly the same theory applies to single yarns, however they are spun. The greater the amount of twist inserted, the more will they shrink in length; because fibres are arranged, not in a line approximately parallel to the axis of the thread, but following a course much more nearly analogous to that of a strand of wire in a spiral spring.

If any thread is held extended by its two extremities, and

twist is then inserted, it is bound to break, sooner or later, if the twisting is continued indefinitely. It is for this reason that when hard twisted sorts are being spun the mule carriage runs back a few inches towards the spindles before the unwinding in the fourth stage begins. This, of course, tells on the weight of the finished yarn. If the rollers stop when the carriage is halfway out, the draft will be 50 per cent. if the twist is so small that the carriage can remain at its full stretch until the twisting is quite complete; but if there are so many turns per inch that it is necessary for the carriage to move in, say, 7 inches, the draft will be reduced from 50 per cent. to 40 per cent.; so that the 20-skein roving will not be drafted to 40 skeins, but to a 36-skein yarn.

FOURTH STAGE—BACKING-OFF.

1. Rollers (R) standing.
2. Carriage (K) standing.
3. Spindles (S) unwind a few turns slightly to the left.
4. Faller wire (F) depressed.
5. Counter faller wire (C) lifted.

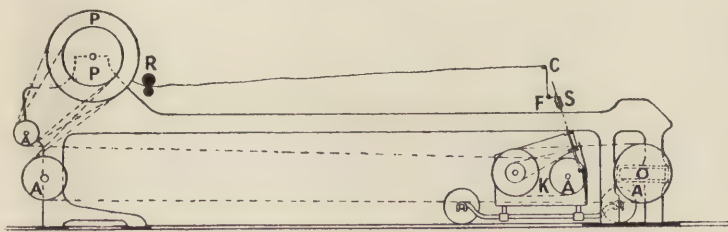


FIG. 91.

In this stage the thread that is wrapped in spiral form round the spindles, above the cop is unwound. In the three

previous stages the faller and the counter faller wires have had no part in the treatment of the thread. It is the function of the faller wire to direct the thread on to the cop when the carriage is running in, whilst the thread is being wound on to the cop. The counter faller wire fulfils a simpler but no less necessary purpose. It takes up the slack yarn which is unwound from the cop, and so alters its position during the run-in of the carriage that there is always a right amount of tension on the yarn.

This sounds extremely simple, but in practice it is found necessary to have the adjustment very accurate indeed. In addition to the complicated mechanism that controls both the wires, it is therefore necessary that these subsidiary appliances should receive the personal attention of the minders.

The whole of this subject is too complicated to be made clear in writing; but if the reader remembers that there is a much greater number of spirals to unwind and take up when the spindle is empty, than when the cop is all but complete, he will understand that, like all other parts of a mule, the wires are both controlled by movements that are much more intricate than they appear to be at first sight.

5TH STAGE—WINDING-ON.

1. Rollers R, standing.
2. Carriage K, running in, towards the rollers.
3. Spindles S, revolving very slowly to the right.
4. Faller wire F, directing the yarn on to the cop.
5. Counter faller wire C, taking up slack yarn to adjust its tension.

During this stage the difficulties that have to be overcome are almost entirely mechanical. It is only necessary to make spindles revolve at a suitably variable speed. This is, however, a very intricate problem indeed, because the surface traverse of the cop, at the point where the thread is being wound on to it, at any given moment, must so nearly equal the carriage speed, that the counter wire can adjust the difference between the two, without increasing or diminishing the strain on the thread.

To guide the thread on to the cop is the work of the faller wire. At the close of the fourth stage it is in the position

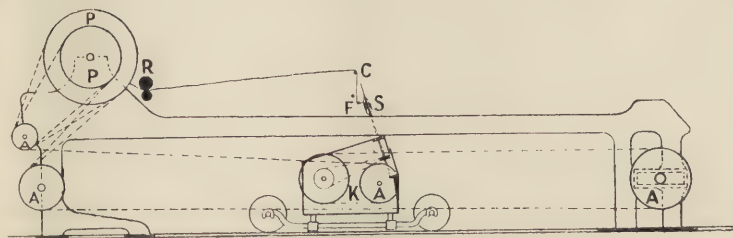


FIG. 92.

shown in Fig. 91,—a position at right angles to the spindle at the point to which the nose of the cop extends. This is different every time the carriage runs in, because the cop grows in length continually. As the carriage moves towards the rollers, the faller wire drops rapidly until it is opposite to the lowest portion of the pick. In this way it winds on the yarn which forms the steeply-descending spirals. It then begins to rise slowly, winding the yarn on to the cop in coils that get steadily smaller as the carriage nears the roller. This involves a steadily increasing ratio in the speed of the spindle to the speed of the carriage. It is a speed that would be intricate in any case, even if it were not complicated by the

fact that the speed of the carriage is continually varying. There are few pieces of mechanism in the textile industry so complicated as the combination of wheels, scrolls, clutches, and pulleys which control all these various actions of the mule. How they were first devised, and their action synchronized, is still a complete mystery to the writer, and it is no use pretending that the whole of them can be made plain to every reader in such a work as this.

It is stated, on first-hand authority, that a Japanese foreman, who had never worked a mule, went two days' march to see one running in a neighbouring factory. He spent two days in watching the machine at work, and then he walked back home. Two mules were there, in cases, newly come from England. These he unpacked, set up, and started, without the maker's aid. It is given to few men to have such an insight into the meaning of mechanism as was possessed by this little Oriental; but his methods were those which must be followed by all who would really understand the work they have to do.

First, the student must comprehend all that has taken place in every phase of the action of the mule, and in this he could be greatly aided by reading.

Secondly, he must observe for himself how various spindles, rollers, wheels, and cams play their respective parts,—how they are started, how they are driven, and how they are thrown out of gear when their work is done. This can only be done by watching a mule in action and at rest.

Finally, if he aspires to a knowledge of the machine which will enable him to set it for any class of work, he must understand the relation between the various parts of the headstock, the spindles, and the carriage. This can be explained in

writing and by diagram, but should be assimilated beside a mule, as before stated.

The intermittent action of the various parts are as follows :—

The rollers :

1st stage, running.

2nd, 3rd, 4th, and 5th stages, standing.

The spindles :

1st stage, slow speed to the right.

2nd stage, „ „ „ „

3rd stage, fast speed to the right.

4th stage, dead slow, a few turns to the left.

5th stage, dead slow, winding on to the right.

The carriage :

1st stage, running out quickly.

2nd stage, running out more slowly.

3rd stage, stationary, or moving a few inches towards the rollers.

4th stage, standing.

5th stage, moving slowly towards the rollers.

The faller wire :

1st, 2nd, and 3rd stages, out of action.

4th stage, depressed.

5th stage, guiding the thread on the cop, in varying positions.

The counter faller wire :

1st, 2nd, and 3rd stages, out of action.

4th stage, raised.

5th stage, taking up slack yarn, in varying positions.

ROLLER DRIVE.

The driving of the rollers is relatively simple, because they only revolve in one direction, and they always revolve at a constant speed so long as they are in motion at all.

In Whiteley's two-speed mule, the rollers are driven from the rim shaft by the simple arrangement shown in Fig. 93. All the time that they are in motion the main belt is on

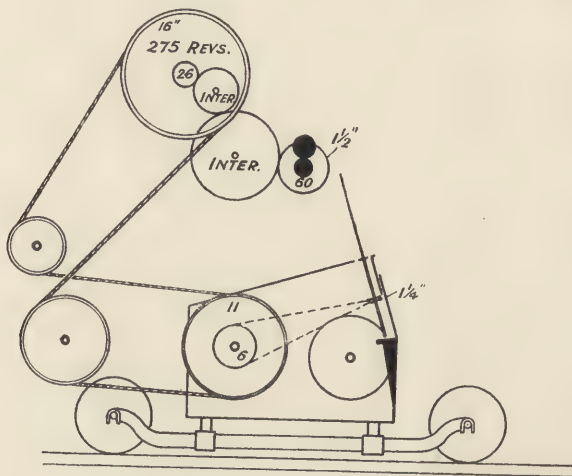


FIG. 93.—SPINDLE AND ROLLER GEARING.

pulley P, which is directly coupled to the change rim pulley, and through it to the tin roller pulley, and to the spindles in the carriage. Therefore, whilst the rim shaft is making 275 revolutions per minute, the spindles are running

$$275 \times \frac{16}{11} \times \frac{6}{14} = 1920 \text{ revolutions per minute}$$

But it will be seen that the gearing will drive the rollers from the same shaft $275 \times \frac{26}{60}$, or 119 revolutions per minute, or—

$$275 \times \frac{26}{60} \times 1\frac{1}{2} \times 3\frac{1}{7} = 520 \text{ inches per minute output}$$

showing that, however long the rollers and the spindles run, they will be putting into the yarn $1\frac{9}{5} \frac{20}{20}$, or very nearly four turns per inch. As no drafting is going on at this time, the thread must contain four turns per inch when the rollers stop and drafting begins.

The arrangement which regulates the stoppage of the rollers is a small group of finely toothed wheels, driven from the roller shaft inside the headstock. They really form a

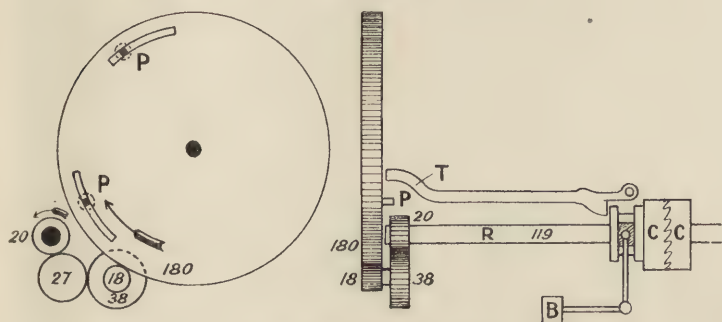


FIG. 94.—KNOCKING-OFF GEAR.

counting motion, or knocker off (see Fig. 94). The largest wheel in the group carries a peg, P, which may be placed in any position near to the periphery of the wheel, the rollers being stopped by the peg as soon as it has rotated far enough to lift the trigger T, which releases the clutch C.

The amount of draft is, therefore, entirely dependant on this peg and the rotation of the wheel which carries it, for the carriage traverse is always the same for similar counts, and the amount of extension may be calculated by placing the number of inches paid out by the rollers over the number of inches in the draw of the carriage. Thus, the roller shaft R runs 119

revolutions per minute when it is delivering 520 inches of yarn, and the rollers might deliver 60 inches before they stop; but—

$$119 \times \frac{20 \times 18}{38 \times 180} = \frac{120}{19} = 6\frac{1}{5} \text{ revs. of the peg wheel per min.}$$

and if the two pegs are two-thirds of a revolution apart, the rollers will deliver $\frac{2}{3} \times \frac{19}{120} \times 520 = 55$ inches before they stop.

The whole of these operations take place during the first stage; in fact, the first stage is really ended by the peg at the moment that it stops the rollers.

If a mule were empty, and were run with the knocking-off gear out of action, it is true that, during one complete draw and return, the rollers would revolve at all kinds of varying speeds. As it is, the clutch box and the spindles do move at speeds that bear a constant relation to one another, but this has no bearing whatever on the movement of a mule in practice. The rollers run for a definite length of time, which they themselves regulate, and whilst they are in motion, their speed is **always uniform**, so long as they continue to make a given kind of yarn. They then remain motionless throughout the remaining four phases. It is, therefore, now only necessary for us to notice how they are again put into action at the beginning of another draw.

In some types of cotton mules there are five different cams on the cam shaft for the control of various important movements at the exact time which is necessary, but in the woollen trade a different plan is adopted, and in the mule under discussion almost every separate part has one or more special cams, or trains of wheels which control it, and have no other work. Thus we find—

First.—That the rollers are driven at the required speed from the rim shaft by train of wheels (see Fig. 93).

Second.—They are thrown out of gear by the motion shown in Fig. 94, as soon as they have paid out a requisite length of yarn.

Third.—They are started again by the carriage itself.

This is accomplished in the simplest possible way by a stud so attached to the carriage that it lifts the bowl B (Fig. 94), and thrusts the clutch box into gear, just as the spindles reach the rollers, ready to begin another draw. Students who are acquainted with worsted machinery must be very particular to bear one thing in mind.

The wheel corresponding to the twist wheel in the train between the rollers and the spindle (see Fig. 93), has nothing whatever to do with the total number of turns per inch in the finished yarn. Its work begins and ends with the insertion of the drafting twist, as is pointed out on page 266, and this section of the twist is of utmost importance in the production of a satisfactory yarn. In a long stapled quality too many turns will make the fibres set, so that they will not draw. Too few turns in a short material, on the other hand, will leave the fibres without cohesion, too little set, so that they break or draw unevenly.

Nothing but the intelligent use of long experience will guide a man safely in the selection of a twist for this phase. Almost every class of fibre, whether cotton, mungo waste, or wool, will require different treatment, just as they will require a different kind of draft.

The final number of turns which the yarn contains has nothing whatever to do with the rollers. It is obtained by counting the number of turns that the rim shaft makes, both while it is on the fast speed and whilst it is on the slow. It is then stopped at the right moment. The speed of the rim

shaft can of course be worked out into revolutions of the spindles, for though the speed of the spindles varies in relation to the speed of the belt, their speed is always seven times the speed of the rim shaft, so long as the smaller rim pulley is 16 inches in diameter. It must nevertheless be borne in mind that the graduations in the peg twist wheel are only intended to be relative to each other, and must not necessarily be regarded as indicating a definite number, either of turns per inch or revolutions in a given time. All that we can say is, that the wheels given in Fig. 97 will make the peg twist wheel revolve once to every 443 revolutions of the rim shaft, or 3031 revolutions of the spindle. Thus—

$$\frac{15 \times 12}{26 \times 30 \times 100} = 433$$

If the length of the draw is 72 inches, this means that a total of 42 turns per inch can be inserted whilst the wheel makes one revolution, and any proportion of 42 can be counted out by the simple expedient of moving the peg P to any desired position in the dovetailed slot B.

This small but important piece of self-contained gearing (see Fig. 97) is so arranged that the toothed wheels 100 and 12 fall out of gear when the belt is thrown off. By means of a spring, the wheel 100 then turns back to zero automatically, and is ready to begin counting out the twist for another draw as soon as it shall be lifted into gear again, when the carriage reaches the rollers at the end of the fifth or final phase.

SPINDLE DRIVE.

Spindle drive is one of the greatest mysteries about a mule, largely because a keen observer will find it hard to tell which

pulleys and ropes are drivers, and which obtain their motion from sections of the machine like the carriage, which they only appear to drive. As a matter of fact, the spindles are under the control of four entirely different systems of driving. To understand how this is possible it is not only necessary to understand the construction of the rim shaft, but also the relations to one another of the various pulleys and wheels that it carries. It is driven—

In the first phase by the belt, when it is on the pulley C for slow speed to the right.

In the second phase by the belt, when it is on the pulley C for slow speed to the right.

In the third phase by the belt, when it is on the pulley P for fast speed to the right.

In the fourth phase by the rope pulley R (Fig. 98) for slow unwinding to the left.

In the fifth phase from the tin pulley through the rim cord and the rim pulley whilst the belt is on the loose pulley, all other motions being out of gear.

This motion of the shaft is, of course, no value. It takes place simply because the rim shaft must move with the spindles, which, during this phase, are rotated by the quadrant at a slow and variable speed which gives such a surface traverse to the cop that the yarn is wound on to it at exactly the same speed that the carriage moves in. Fig. 95, where the rim shaft is shown in section, may be some aid to the student in explaining how these things take place. Of the three pulleys that it carries, the centre one only is quite loose, so that when the belt is on it, it simply revolves without doing any work, and the rim shaft may then be moved in any direction by any other means without hindrance. The left-hand pulley C is keyed

fast to the shaft itself, so that when it moves, the train of wheels which drive the rollers (see Fig. 93) and the smaller rim pulley, SR, which is also made fast to the shaft, make the same number of revolutions as the pulley.

It is when the belt is on the pulley P that the drive is most complicated. On the shaft A there is a sleeve, B, that extends

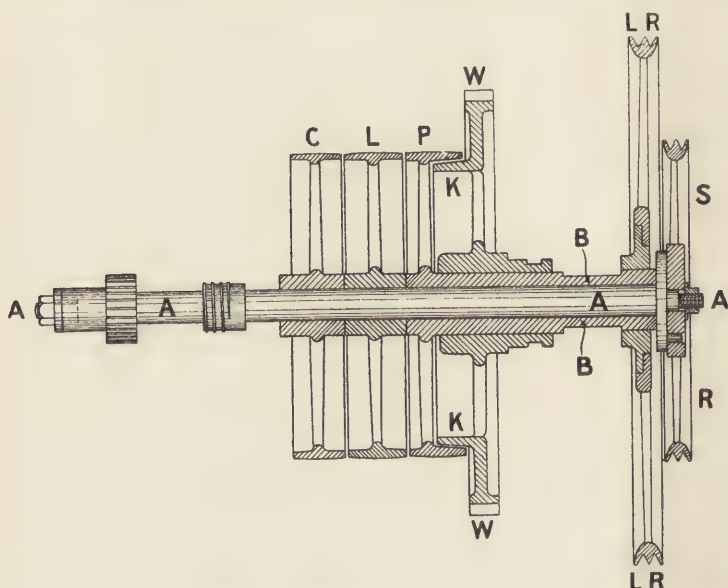


FIG. 95.—SECTION OF RIM SHAFT.

right through the spur wheel W, the clutch K, and the frame to LR the larger rim pulley. The pulley P and the large rim pulley are fast to the two extremities of this sleeve. The spur wheel and the clutch through which it moves have no connection with it. They can rotate on the sleeve exactly as if it were a shaft on which they are loose pulleys.

It is only necessary to note one further particular as to the drive. The arrangement of the rope which drives the spindles

is very complicated and very ingenious (see Figs. 90-96). It is so arranged that the rope goes over both the large and the small rim pulleys, and hence it is an absolute necessity that the surface speeds of the two rim pulleys must always be exactly the same. But if the surface speeds of these two pulleys of different size are equal, the speed of their respective shafts must always differ in exact relation to the diameter of the two pulleys; in other words, if the rim pulleys were 13 and 26 inches in diameter respectively, the small pulley must always be going double the speed of the large pulley. It does not matter by whatever means the spindles are being driven, the speed of the

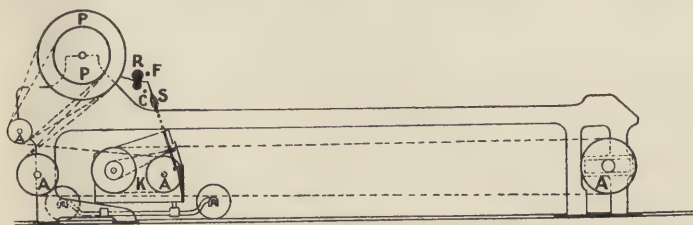


FIG. 96.

roller shaft and of the clutch must therefore bear a definite relation to theirs.

Phase one.—As already stated, when the spindles are on the slow speed, they are driven through the pulley C (Fig. 95), which is coupled direct to the rim pulley R, from which the rope is carried over the angle pulleys A, A, A to the tin roller pulley, which moves with the carriage K (Fig. 96). The rope is maintained at equal tension in whatever position the carriage may be. This is entirely due to the ingenious system of pulleys employed, and after it has once been thoroughly understood, all parts of it may be entirely neglected in the calculations for twist, except the two rim pulleys and the tin roller pulley.

The calculation for revolutions per minute in this phase is also comparatively simple—

$$\begin{aligned}\text{Speed of rim shaft} &= 275 \times \frac{61 \times 6}{11 \times 1\frac{1}{4}} \\ &= 1920 \text{ revolutions of spindles per minute.}\end{aligned}$$

In the second phase the spindles continue to run exactly the same speed, though the speed of the carriage may be varied by the scrolls to suit the amount of attenuation and the relative amount of twist in the yarn that is being spun. This is the duty of the scrolls (US, Fig. 98).

The third phase begins the moment the carriage stops and the drafting ceases. The draw of 72 inches of yarn may then contain $5\frac{1}{2}$ turns per inch, or a total of 400 turns. It may also require a total of 25 turns before it is strong enough for use. This means that $(25 - 5\frac{1}{2}) \times 72$ or 1400 turns must now be put in, in the shortest possible time. For this purpose the spindles must go at their highest possible speed. The belt is thrown from the pulley C on to the pulley P which is connected directly with the large rim pulley L R, which now makes exactly the same number of revolutions per minute as that at which the smaller rim pulley was previously rotating; but as its diameter is 10 inches larger, the speed of the spindles is increased in that proportion, as is that of the small rim pulley, which now becomes a driven or counter pulley doing no work at all (see Fig. 95).

This third period continues until sufficient turns per inch have been inserted to make the yarn strong enough for use. If 20 turns per inch are required for a 72-inch stretch the total number will obviously be 1440 turns, whatever the speed of the spindles may have been. This number of turns

is counted out by a train of screws and wheels on the same principle as that used for the stoppage of the rollers; but this one is fixed at the back of the headstock, and is connected directly with the rim shaft, which in its turn is directly connected with the spindles. It has been already shown that

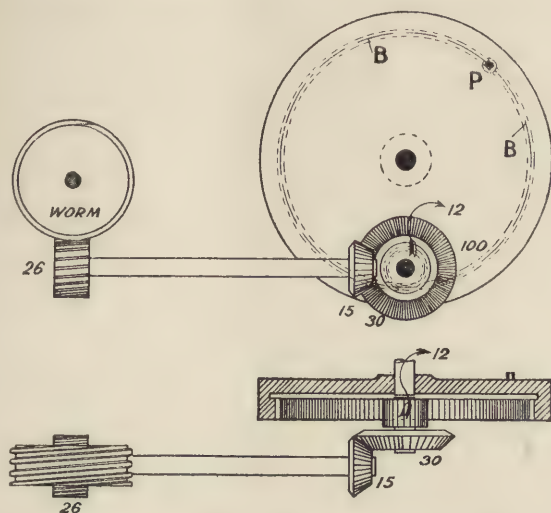


FIG. 97.—PLAN AND ELEVATION OF TWIST GEAR.

each spindle revolves seven times to every revolution of the rim shaft, and it therefore follows that if the spindles are to be stopped when they have rotated 1440 times, the rim shaft must only revolve 205 times. These 205, or any other number of revolutions, are counted out by the screw gear, which makes the plate wheel B and its peg P revolve at such a speed that the peg moves a lever at exactly the right moment. But because $\frac{1}{26} \times \frac{15}{30} \times \frac{12}{100} = \frac{3}{1300}$ or $\frac{1}{433}$, the rim shaft will make 433 revolutions for every complete revolution of the peg wheel B (Fig. 97), and therefore the peg must be set $\frac{205}{433}$ of a revolution from the trigger or lever, at the beginning

of every run out. When this lever is pushed back a catch is released, throwing the belt on to the loose pulley (see Fig. 95). The yarn is now both spun and twisted. Phase 3 is, therefore, complete, and only the backing off and winding motions remain to be completed.

In the fourth and fifth phases the driving is not done by the belt at all, but by the rope and the rope pulley (RR, Fig. 98), whilst the main driving belt is on the loose pulley.

Phase 4 is very short. The moment all twist is inserted and the belt thrown off, so that the rim shaft is free to move in any direction, a wheel in the relieving motion falls into gear with the worm wheel. By this means the large spur wheel W (Figs. 95 and 98), is moved a fraction of an inch to the left, when sufficient time has elapsed for the spindles to come almost to a standstill. The motion is so adjustable that the clutch is thrown into gear more quickly or more slowly, as the case may be, when the mule is running heavily in the morning or more lightly later in the day. The moment that the cone, which extends within the pulley P, is jammed against its hollow conical periphery, it forms a friction clutch, and the consequence is that the pulley and the large rim wheel move slowly in the opposite direction to that in which they run whilst they are inserting twist. The spindles, therefore, rotate very slowly in the reverse direction to unwind the spiral coils of yarn that are wrapped round all that part of them which is above the nose of the cop.

Like all other phases in the action of the mule, this one has to be regulated with the utmost nicety. It must also differ in duration at different times, for it is obvious that more thread is wound round the spindle when the cop is

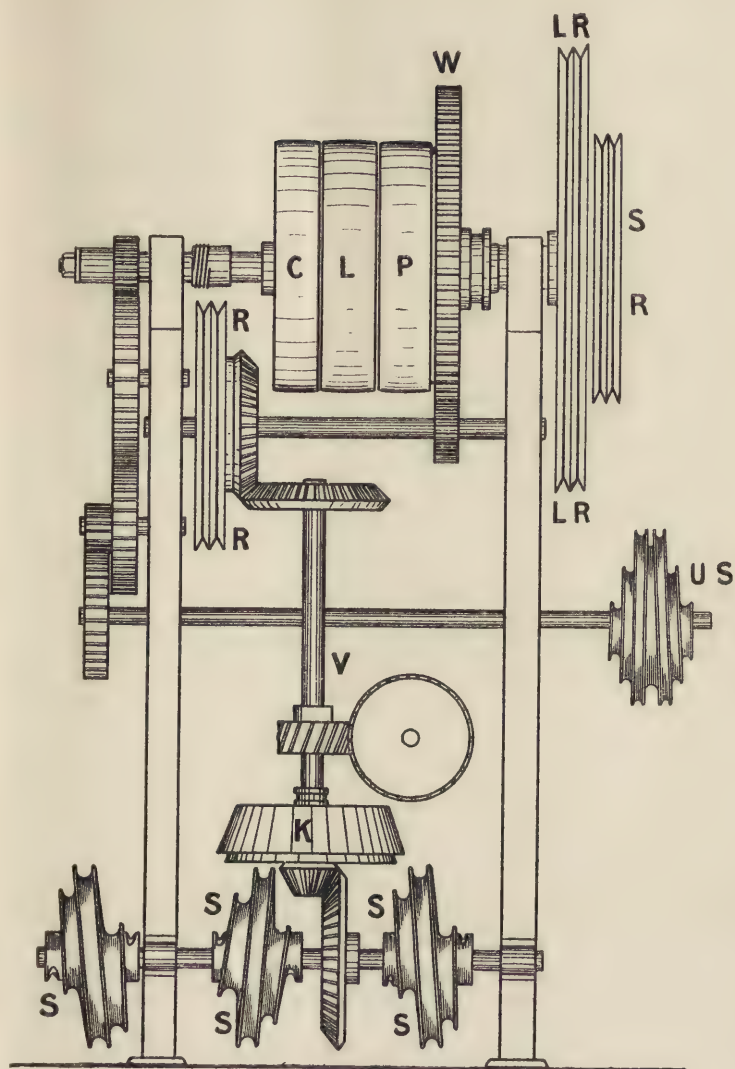


FIG. 98.—BACK VIEW OF MULE HEADSTOCK.

just beginning to be built than when it is practically finished.

During the fifth or final phase, in which the carriage runs in and the yarn is wound on to the cop, the spindles are driven, not from the rim pulleys, but by the motion of the carriage itself acting through the quadrant chain and the barrel. The rim pulleys and the rim shaft move simply because they are connected to the spindles by the rim band (see Fig. 93).

If the various layers of yarn were wound on to the spindle parallel with its axis, it is not difficult to imagine a method by which the speed of the spindle could be made to coincide accurately with the speed of the carriage. It is of course well known that the layers of yarn on every cop are not parallel, but conical. When the yarn is being wound on to the thickest part of the cone, every revolution of the spindle will take up six inches or more of yarn, whereas each revolution will only wind on one inch or less, when the traverse reaches the bare spindle at the nose of the cop.

This means that at one part of the run in, the spindle must go at one-sixth the speed at which it rotates at the beginning and the end, because the thread which is first wound on to the nose of the cop, runs rapidly down to the part of greatest thickness, and then ascends slowly until it again reaches the bare spindle just above the nose. These variations occur during every draw after the cop has once reached its full thickness; but the student must also bear in mind that the first layer which is wound on to the bare spindle or paper tube is so nearly parallel that the speed of the spindle must be practically uniform throughout the entire run in (see Fig. 100).

There is one thing else to remember. The ascent and descent of the traverse take place at very different speeds. The descent is very rapid, to obtain a quick spiral, which cuts the ascending layers of yarn on the cop at a very considerable angle (see Fig. 99).

If this were not the case the various layers of yarn on the cop would have very little cohesion. They would fall apart

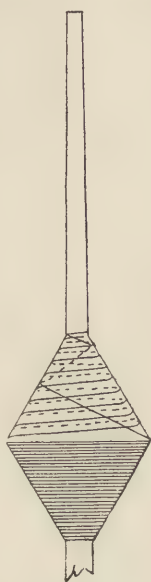


FIG. 99.



FIG. 100.

as soon as the cop was taken from the spindle, unless there were some system of crossing the threads in this way.

In the old days, when warping was done almost wholly from large double-ended bobbins, the breaking of a bobbin head inevitably meant the wasting of all the yarn, because all the layers were parallel with one another, with no cohesion at all. The cross-wound cheese is a perfect illustration of the

strength which can be obtained by much rapid crossing. So much for the results desired: now let us see what is involved in consequence.

For every inch the carriage moves, a spindle must make one revolution when winding on to the bare metal. This occurs for a moment at the beginning of the run in, but as the guide wire drops so fast that it reaches the thickest part of the cop in $3\frac{1}{2}$ revolutions, the speed of the spindle must be reduced to one-sixth part of its primary speed before those revolutions are completed, simply because the cop is six times the thickness of the spindle, and therefore takes up six times as much yarn at every revolution. In other words, it must now move one-sixth of a revolution for every inch that the carriage moves at this particular part of the phase.

If we take it that 18 inches of yarn are required for the downward traverse, it means that the spindle must reach its lowest speed, say of a revolution for every inch moved by the carriage, by the time the latter has travelled that distance (18 inches), after which the speed of the spindles must steadily increase until they reach the rollers.

The Quadrant.—This very complicated motion is obtained through the chain, which is attached at one end to the chain barrel B (which drives the tin roller shaft) and to the quadrant at the other. As the carriage runs out, the chain is wound on to the barrel B by the action of a cord, so that the chain is wrapped four or five times round the barrel when winding on commences. All through the first, second, and third phases the chain drum is inoperative, because the click motion with which it is provided allows the tin pulley shaft to rotate freely without moving the drum at all; exactly as the wheels of a free-wheel bicycle can overrun the pedals. During

the fourth phase, in which the spindles make about twelve revolutions, the barrel is still motionless, because the click motion is out of gear. It is during the fifth phase, which we are now discussing, that the barrel becomes a moving force. As the carriage moves away from the quadrant Q to which the chain is fastened, the chain is drawn from the barrel B, causing it to rotate. It now becomes a driving power. The click motion is thrown into gear by a trigger, and, still acting like the pedals of a free-wheel cycle, it turns the tin pulley 6, and the spindles at

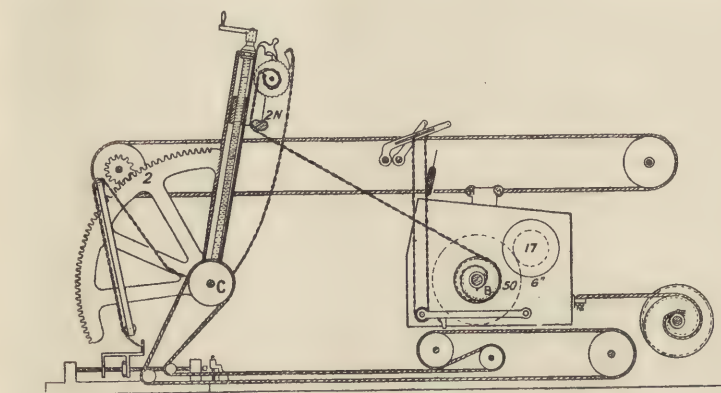


FIG. 101.—MULE CARRIAGE SCROLLS AND QUADRANT.

a speed exactly relative to its own. It is quite easy to see that if the other end of the chain were fastened to some fixed point at the outer end of the headstock, instead of being fastened to the quadrant nut, the number of revolutions of the spindles (and not the surface speed of the cops) would be the same for every inch that the carriage moves (see Fig. 101).

The quadrant is a piece of apparatus which is so designed and moved, that the nut QN to which the chain is fixed, continually alters its position in regard to the carriage. It is so ingeniously adjusted that it is never twice in the same position, and its

movement in every draw bears such a curious relation to the carriage, that it causes the chain drum and the spindles to revolve at just the right speed to wind up all the yarn. This speed is never the same for any two consecutive inches. To understand the principle of the quadrant's action, it is necessary to understand the principles on which cams and eccentrics work; but the result may be made fairly clear by a series of diagrams.

If the nut to which the chain is made fast were placed at the centre A on which the quadrant swings, the result would be exactly the same as if the chain were attached to the head-stock (see Fig. 102). On the other hand, if the nut is wound up to the end of the quadrant arm at *b* by the screw, it is clear that the chain will be pulled from the barrel in quite another manner, because the nut moves 40 inches in the same direction as the chain barrel, whilst the latter moves with the carriage towards the rollers.

If the paper tube on which the cop is built is 1 inch in circumference, it is clear that every spindle must revolve seventy-two times to take up the 72 inches of yarn which reach from the rollers to the spindle-tip. If the diameter of the tin roller is 6 inches, the spindle wharles $1\frac{1}{4}$ inches in diameter, and if they be geared to the chain barrel as shown in Fig. 101, through wheels which have seventeen and fifty teeth respectively, it is clear that each spindle will revolve fourteen times for every revolution of the barrel—that is to say, that if seventy-two revolutions are required, the drum must revolve $7\frac{2}{4}$, or five times, every time the carriage runs in. In practice the drum is made 6 inches in diameter, or 19 inches in circumference. The pulling off of 72 inches of chain will exactly effect this result. When the cops have once

reached their full thickness the calculations alter completely.

Let us say that it will require 4 inches to go once round the thickest part of the cop, and 1 inch for the wrap nearest to the nose, $4 + 1$ divided by 2 will then be the average length of all the wraps in one run-in. That is to say, the average circumference is $2\frac{1}{2}$ inches, and each spindle will therefore only have to revolve twenty-nine times instead of the seventy-two times that was necessary when the spindle was empty. When the barrel is geared to the spindles in the way we have shown, only 29 inches of chain would have to be pulled from it to obtain the

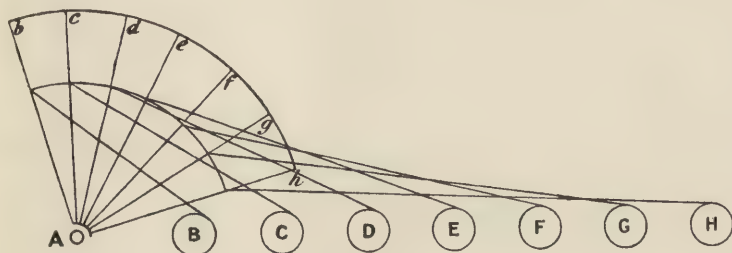


FIG. 102.

required number of revolutions, and, consequently, whilst the carriage is running in, the point of the quadrant to which the chain is fixed must also move in the same direction, so that it only loses twenty-nine inches on the carriage. But $72 \text{ inches} - 29 \text{ inches} = 43 \text{ inches}$, and the nut must therefore move 43 inches as the carriage runs in. If the nut could move in a straight line between the two points *b* and *h* (Fig. 102), which are 43 inches apart, it is clear that the spindle speed, though greatly reduced, would be uniform all the time that the carriage was running in; but as the nut moves along the arc of a circle at a uniform speed, the direct measurement from

the nut to the centre of the chain barrel increases at speeds that are never twice alike. Fortunately, the variable carriage speed need not enter into consideration, because the quadrant is driven from the carriage in such a way that the quadrant must turn a certain number of degrees for every inch that the carriage moves (see Fig. 101). For the sake of simplicity, we will divide the run-in into six different sections, and say that the quadrant must move 120 degrees to give the necessary 43-inch extension.

The diagram in Fig. 102 shows the barrel T moving steadily in the carriage along the line AH, the relation between the length of chain necessary in each case, might be expressed by a series of figures that have no definite relation to one another. It is the most important point to notice that the differences decrease steadily until the yarn is winding on to the thickest part of the cop, and then steadily increase until the carriage is in and the yarn is winding once more on to the bare spindle. In other words, the chain drum begins moving rapidly. It very quickly begins to slacken down to its lowest speed, and from the point *d*, when the nut is about on the letter *d*, it steadily accelerates, until it is practically going at its full speed when the movement of the nut at *h* is very nearly at right angles to the direction of the carriage traverse.

This completes the fifth and last phase of spindle movement. As the carriage reaches the back stops it puts in the roller clutch and throws the belt on to the pulley C (Fig. 98), so that the rollers and the spindles begin the spinning of a second stretch of yarn simultaneously. Students that understand the principles that have been here expounded must not conclude that they therefore understand the practical working of this part of a mule. A large book could be exclusively filled with

particulars as to the movements and adjustments of the various working parts of this extremely complicated machine. This is strictly a dissertation regarding the principles involved, and those who really wish to get a comprehensive grasp of the more intricate details of mechanism and theory are recommended to study the masterly works which have appeared from time to time from the hands of experts on cotton spinning. These works do not describe a woollen mule, but they describe in detail the working parts which are common to all mules, and a student who gets his knowledge of one, and applies those principles to the working of the other, will be far better qualified to adjust the various parts, than he would be if he learned by rote all the special adjustments of some special type of woollen machine.

CARRIAGE DRIVE.

Compared with the complexity of the spindle drive, the mechanism that controls the carriage is relatively simple.

In Phase 1 it is moved away from the rollers by the upper scroll. This is directly driven by the roller gear, see US, Fig. 98, and it ensures that the carriage retreats from the rollers at a speed exactly relative to theirs, so long as the scroll is of the parallel type.

In Phase 2 the same gear remains in action after the rollers have come to a standstill, and again, if the scroll is of a parallel nature, the speeds of the carriage will continue the same. In any case the speed of the carriage scroll will remain constant throughout this phase, although the speed of the carriage itself may be reduced to any desired extent by the use of different kinds of scrolls. The phase is ended by the cam shaft, which is made to act upon the main lever of the headstock at exactly

the right moment, as the carriage reaches the end of the run out.

During Phase 3, when the spindles are driven at top speed by the large rim pulley, the carriage has to run in from 2 to 7 inches to allow for the shortening of the yarn by the insertion of so many turns of twist.

This is arranged for by the **jacking motion**, which is a small piece of mechanism attached to the carriage within the sides of the headstock. It consists of a rack and pinion motion which is driven through a worm wheel from the tin-roller shaft, but is only thrown into gear by a trigger just as the carriage reaches the back stops. It is therefore only in action whilst the spindles are putting in the extra turns of twist. The more the turns, the greater will be the distance that the carriage moves during this phase. As the rack is moving slowly out all the time that the spindles revolve, the end of it is pushed steadily against one of the stops, and it therefore follows that the longer the spindles run, after the carriage has reached the end of a draw, the further in will the carriage be pressed, by the automatic action of this little jacking motion. It is exceedingly simple, both in theory and practice, and it is consequently efficient.

During the short Fourth Phase, when the spindles are unwinding from six to twelve revolutions, all the clutches are out of gear, the scrolls are stationary, and the carriage is at rest. The driving during this and the following phase is done entirely by the rope pulley R on the back cross-shaft (see Fig. 98). So long as phase 4 lasts, only this shaft and the cam shaft are in motion, but as soon as it is complete, the clutch K on the vertical shaft V is thrown into gear by the action of the cam shaft on the big complicated lever that plays so many parts in the

control of the various phases. When the clutch K is once in gear, the low scroll shaft is driven through the bevel wheels, and the carriage is drawn in, as the rope is wound on to the scrolls S by their revolution. The student will notice that the scrolls are three in number—one outside the headstock frame the other two within it. Two are cut to the right, and one is cut to the left. All are identical in other respects. All rotate in the same direction on the same low scroll shaft. The carriage is drawn in by the two scrolls that run from right to left, but it is so heavy and it is pulled in so quickly that it would overrun

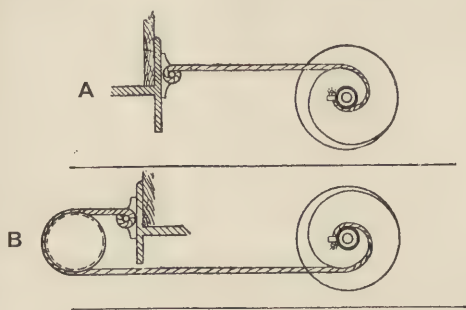


FIG. 103.—SCROLL AND CHECK SCROLL CONNECTIONS.

and bump into the back stops with a severe jar, if it were not retarded by some effective means. The scroll that winds from left to right is used for this control. It pays out exactly as much rope as the other two take in, and as this rope runs round the counter-pulley (Fig. 103), it ensures that the motion of the carriage shall correspond exactly with the design of the scrolls, and shall never overrun them.

The shape of the scrolls is very peculiar, but their design is not difficult to understand, if the purpose of their peculiar construction is once understood. In order to make the output of the mule as large as possible, it is necessary that the carriage

should run in, in the shortest possible time; but, on the other hand, it is impossible to make the heavy carriage begin suddenly to travel rapidly towards the rollers. The scrolls are therefore designed to start the movement slowly, to accelerate it rapidly until full speed is reached, and then to retard it gently until the spindles near the rollers, and finally to stop it without unnecessary vibration.

All the time that the clutch is in gear, the scroll shaft is rotating at a uniform rate, and the shape of the scrolls is what it is for the simple purpose of translating a uniform velocity into an accelerating velocity. A scroll may be designed to give almost any required combination of speeds. If it were so desired, the carriage might be made to traverse the first part of its journey at a slow uniform speed, the middle part of its journey at a uniform fast speed, with any other uniform speed until it stopped. To obtain such a motion, it would only be necessary to design a scroll that would wind 24 inches of rope in six revolutions round a drum 2 inches in diameter, the middle half of the rope round a drum of 12 inches diameter, and the last 24 inches round another drum of 2 inches diameter. All that is necessary is to decide on the speed in inches at every portion of the run in, and to design a scroll to correspond. Let us say, for example, that the scroll shaft has a speed of 51 revolutions per minute, and that it is desired to get the carriage in in six seconds; the whole journey must then correspond with five revolutions of the scroll.

During the first two revolutions the speed must steadily accelerate. During the third revolution the speed is at its highest limit. During the fourth and fifth revolutions the speed is steadily diminishing.

If the speed during the first 6 inches is to be 5 inches per

second, the diameter of that part of the scroll must clearly be 2 inches; and if the speed for the middle 6 inches is to be 20 inches per second, the largest diameter of the scroll would be about 8 inches. This means that in the 18 inches between the 6th inch and the 24th, the size of the scroll must increase from 2 inches to 8 inches (see Fig. 104). To design a scroll which will give a regular rate of increase, it is only

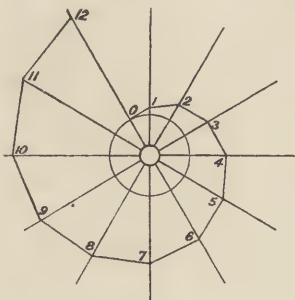


FIG. 104.

necessary to draw a series of lines from a centre, each at a given angle from the next (see Fig. 104), and mark on each of them a point as shown, the rate of increase being uniform. The points are then connected and the corners rounded off.

There are many reasons why a scroll should not be made of exactly this design; as a matter of fact, the carriage speed accelerates steadily until the time arrives when it must begin to be retarded. In this case, the acceleration would be from a 2-inch to an 8-inch diameter in 34 inches of take up. For only 4 inches in the middle of the run in would the carriage be moving at top speed. Whatever type of scroll is selected, it is obvious that all three scrolls must be exactly alike in design, although the check scroll is made to wind in exactly the opposite direction, so that it is paying out rope at exactly the same speed that the others are winding on.

If the carriage were very short indeed, so that it extended on either side of the headstock to a distance of only 8 or 10 feet, it is conceivable that it might be built so rigid that it could be moved in and out by the three headstock scrolls alone; but in a mule of five hundred spindles, with a carriage

100 feet or more in length, it is utterly impossible to move the carriage from one point only, and other means have therefore to be adopted to draw the ends in and out, at a speed that will keep the whole carriage parallel. There are two methods in regular use. The first and commonest is by squaring bands. In the second, which is very common in the cotton trade, an auxiliary shaft is used, which has a variable motion imparted to it by another scroll set apart for this particular purpose.

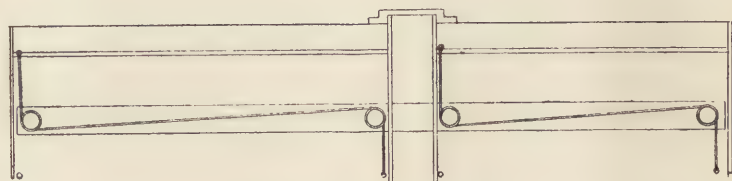


FIG. 105.—SQUARING BANDS.

Squaring bands are a device of extreme simplicity and ingenuity. Their application is usually limited to one set of cords. That is to say, a carriage so controlled is pulled in and out at its two extremities, or kept square, so that the spindles most distant from the headstock and those close to it are always equidistant from the rollers. But if a mule contains a very large number of spindles, so that the carriage is unusually long, it is possible that the spindles halfway down either side of the mule may be slightly out of line, for there is certain to be a slight amount of spring, however stiffly a long carriage may be built. For example, the unstayed portion in the centre will tend to lag behind as the carriage starts simply because of its weight, and it is also likely to happen that, when it has acquired full speed, and the ends and centre are being retarded, the momentum on that part which is farthest from

the control of any cord may carry it in advance of the calculated speed. This would, of course, be fatal to the fine counts.

In Fig. 105, each of the squaring bands that control one side is shown separately, although both run round the same pair of carrying pulleys. One is used exclusively for drawing out the ends of the carriage, the other is for drawing them in.

In order to avoid all possibility of spring in the movement of the carriage, another method is adopted in the cotton trade. As already stated, the low scroll shaft carries an additional scroll (see Fig. 106), the business of which is not direct connection with the carriage, but the driving of a shaft, H, by means of a plain barrel, C.

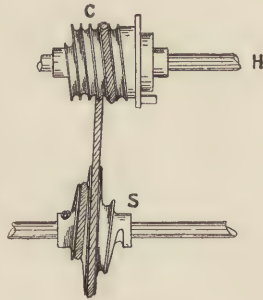


FIG. 106.

It is clear that if the rope is drawn from this plain barrel, C, by a scroll, S, at a continually varying velocity, the revolutions of the shaft must then bear a direct relation to the speed of the rope at any given moment. Any barrel on that shaft which has a plane surface, in such a case, would wind up or pay out rope at exactly the same speed as the scroll itself. In a mule fitted with such a shaft, barrels can be attached at any point, and ropes can be carried from them to the carriage in such a way that every portion of it must come into, or move away from, the rollers at exactly the same velocity. This system is, however, seldom employed in the woollen trade.

FALLER WIRES.

The movements of the faller wire and the counter faller wire are too intimately connected with one another to be considered altogether separately.

They are both entirely out of action during Phases 1, 2, and 3. In Phase 4 the faller wire moves down until it is opposite the nose of the cop, whilst the counter faller wire moves up, to take up the slack yarn which is unwound from the spindles by the backing-off motion.

In Phase 5 it is the duty of the faller wire to direct the yarn on to the cop during the process of winding on, whilst the counter wire rises sufficiently high to put a slight tension on to the yarn. The latter is most easily understood, if it is regarded as a balance weight during the whole of the time that it is not out of action. Its only duty is to keep the threads taut, or to prevent them from being unduly strained when the speed at which the cops are taking up yarn is slightly greater or slightly less than the carriage speed. For example, it is easy to see that the quadrant will not regulate the chain in such a way as to make the spindles move as quickly at the beginning as at the end of the run in; although at both the very beginning and the very end of the run in, the yarn is wound on to a diameter very little larger than that of the bare spindle. In winding the first 12 inches, the spindle ought to move at all speeds between the fastest and the slowest, but this is not the case; its actual fastest speed would be about correct to wind the yarn on to the cop about halfway up the traverse. For the first 6 inches the carriage is running in faster than the cop is taking up the yarn. Each cop would, therefore, be badly built if the counter wire were not able to take up this slack yarn. It is so weighted that if the whole of the threads were suddenly to tighten they would pull it down rather than break.

During winding (see Fig. 109) the whole weight of the lever M and the chain are tending to raise the wire C as far as possible; but during backing off when the carriage is in, a floor incline

is provided that relieves the tension during backing off. It has already been pointed out how the spindles are driven during the run in of the carriage. They are not driven direct from the headstock, but are moved from the carriage itself. Their speed has, therefore, an accurate relation to the movement of the carriage. The same is true of the faller wire. When it is in action the lever that controls the wire is resting on a rail that extends the whole length of the headstock. This rail is not flat, but is composed of two inclines, one ascending rapidly for the first 12 inches of the run in, the other descending slowly all the way from the apex to the rollers (see Fig. 107).

This arrangement is very easy to understand from Fig. 107, where cops are shown at five different times during the run in. It will be seen that the position of the faller wire always bears a direct and double relation to the incline. If the copping rail were a fixture, the faller wire would rise and fall to exactly the same extent and in exactly the same plane, however long the mule were to run. Such a motion would, of course, only build the yarn into a ball near the base of the spindle. To make a cop it is necessary that in each succeeding draw the average height of the wire should be a little greater, so that it will arrange the yarn as shown in Fig. 100. During the first few draws that the mule makes the yarn is wound in almost parallel layers on to the spindle (see Fig. 100), but as building advances the top and bottom cones of the cop become visible, and they continue to grow until the cop has attained to its full thickness; at which time both of them are complete. It is clear that no fixed copping rail could ever do work of this description. It must be possible to let the rail descend steadily and alter its inclination slightly in so doing. For this purpose the copping rail is supported at both ends on inclined planes (A and B, Fig. 107), which

are known respectively as the front and back plates. In addition, in most mules there is an inclined plate, and all the three are controlled by the shaper screw, which slowly draws them in the same direction, allowing the copping rail and the loose inclined plate to move steadily, all through the filling of the cops.

If the yarn were to be built on to a pirn that had its bottom cone already complete, it is clear that a simple lowering motion would do all that is necessary; but it was pointed out, in regard to winding on, that the motion that takes place when winding the parallel layers on to the spindle is quite different to that which is necessary when the full thickness is attained. The

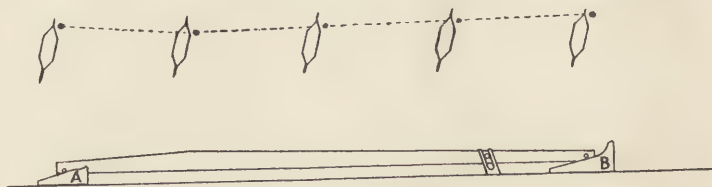


FIG. 107.—COPPING RAIL.

same is true of the copping motion, and consequently the front and back plates are designed with slopes that are not uniform in angle throughout. The back plate is very steep for the first inch or two, whilst the front plate has a concave slope. These portions of the plate play their part in the alteration from parallel to conical winding, but as soon as the two cones attain full length, the long incline of the front plate comes into action, and the rail drops steadily during the formation of the cylindrical portion of the cops.

Like all other parts of the mule, the movement of the faller wires is intermittent; but they must both come into action with the utmost accuracy in regard to the position of the carriage and the movement of the spindles, and for this

reason they are controlled both by the spindles and by the carriage. As the carriage runs out with both wires out of action, one above and one below the threads, they are held steady by the action of springs and weights that is shown in Fig. 108.

The spring S is made just strong enough to hold the faller wire up in the position shown, because the arm to which the chain is attached is at this time nearly vertical. The effect

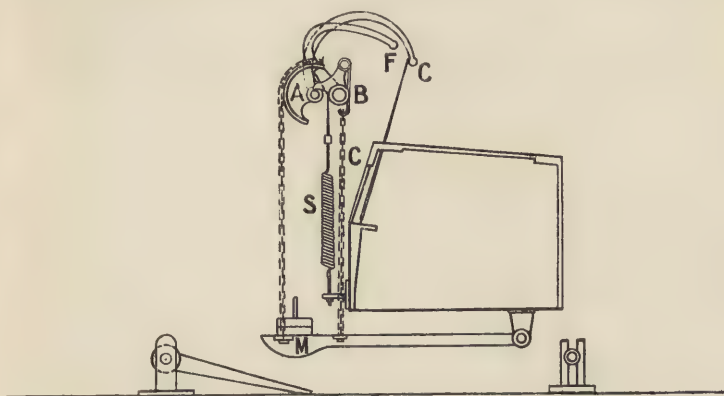


FIG. 108.—COUNTER FALLER OUT OF ACTION.

of the pull of the chain is therefore very slight until some movement takes place. It has been pointed out already that the movement of the wires must synchronize with the backing off by the spindles, and it is therefore the reversal of the spindle motion that is made to pull the faller wire down. Just as the click wheel and the chain barrel control the movement of the spindles, so another "snail" on the tin pulley shaft is arranged to pull the faller wire down the moment the spindles begin to move in a reverse direction. The "snail" exactly resemble the pedals of a free-wheel bicycle, because the shaft can overrun it in one direction

without having any effect at all; but it is so arranged that it will move the moment the direction of rotation is reversed. This "snail," like the chain barrel, winds up a chain as soon as it comes into action. In other words, the moment the movement of the spindles is reversed the chain is wound on to the snail, and the faller wire is thereby pulled down until it is level with the apex of the cop (see Fig. 109). This pulling down of the wire has two distinct effects.

First, it throws the whole series of wires and levers (shown

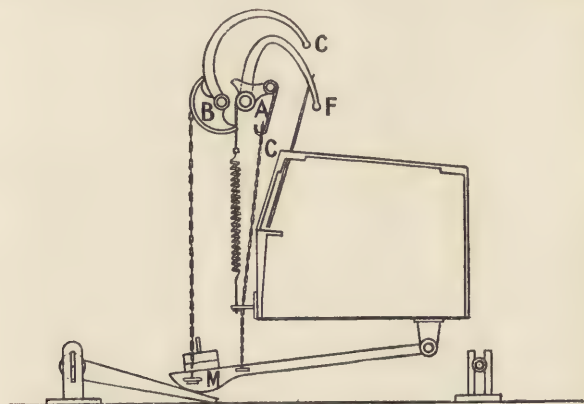


FIG. 109.—COUNTER FALLERS IN ACTION.

in Fig. 108) into another position of equilibrium. The arm A, to which the chain C is attached, is lowered to a horizontal position. This allows the weighted end of the lever M to fall a few inches, and thereby the whole of its weight is thrown on to its outer chain, which is fixed to a series of sectors attached to the counter faller shaft B, and it therefore causes the counter faller to rise against the threads until the strain upon them is sufficient to prevent any further lifting.

In order to build the cops sufficiently hard, so that there may be no chance of snarles occurring in the yarn, let us

say that each thread should have a tension equal to 4 ozs. If the mule has 400 spindles, this means that all the levers and the weights should exercise a tension of 100 lbs. on the counter faller wire; but the radius of the segment B is only half as great as the distance of the counter faller wire from the counter faller shaft, and therefore the total weights of all the levers, with their weights in the mule, will need to be no less than 200 lbs. This involves the supposition that the swan necks are exactly balanced by the segments (see Fig. 109).

The second effect is the locking of the faller wire F and

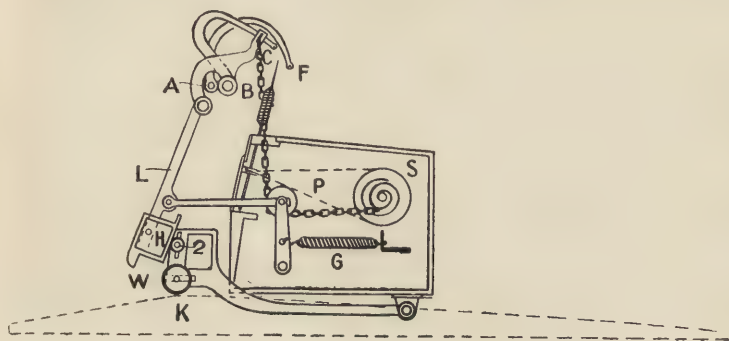


FIG 110.—COPPING RAIL AND FALLER CONNECTIONS. FALLERS UNLOCKED.

its connections in such a way that the wire itself comes under the control of the bowl W, that runs on the coping rail K (Fig. 110). To understand this, we must look at a section of the carriage, immediately over the coping rail, within the headstock. Fig. 110 shows the arrangement of the parts when the carriage is running out, whilst the wires are out of action in the state of equilibrium there shown. The mechanism by which the faller wire is first moved from this position of inaction is shown in Fig. 110, where the lever L is simply hanging from the arm A on the faller shaft, as a dead weight

which tends to keep the faller wire up at its highest point. It remains in this position until the carriage reaches the extremity of the outward run; but the moment the spindles begin to back off (*i.e.* rotate in the reverse direction) the snail begins to move, winds up the chain, pulls down the faller arm F, and raises the other arm A, to which the lever L is attached. All the parts are so adjusted that by the time the wire is level with the cop nose, the sliding piece H at the bottom of the lever L is level with the top of the bowl Q

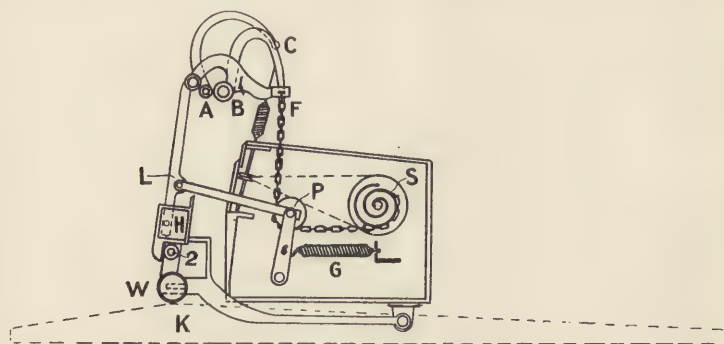


FIG. 111.—COPPING RAIL AND FALLER CONNECTION. FALLERS LOCKED.

and a spring, G, is free to pull the lever L into the position shown, and to hold it there. But the chain pulley P round which the snail chain works is moved towards the snail by the movement of the lever L. This slackens the chain, allowing the faller to rise as far as possible when the sliding part H is in the position shown in Fig. 111. As soon as this position is reached, the faller wire is in rigid metallic connection with the bowl W and the coping rail K, and it must be clear to every reader that in such a position the rise and fall of the bowl on the coping rail, must lower or raise the faller wire, according as the slope of the rail is ascending or descending.

Locking should take place when the faller wire is slightly below the nose of the cops, and this implies that backing off, or the reverse movement of the spindles, should cease at the same moment. The stoppage of the spindles will, of course, mean that the snail chain will also come to a stand. But the reader must bear in mind the obvious fact, that backing off must be of different duration at different parts of the copping, and that different lengths of chain must therefore be wound on to the snail at different times, to secure different heights in the adjustment of the winding wire.

Here again we are met with a difficulty. The height of the wire will not correspond with the number of spindle revolutions at different parts of the doffing. If we take it that 20 revolutions are necessary to unwind all the spirals that are wrapped round the spindle when the cops are only 1 inch in length, and that only 4 revolutions are necessary when the cop is full, the movement of the wire at these different times apparently ought to be in the relation of 4 to 20, but this is certainly not the case. The distance that the faller descends has a definite relation to the spindle's movement, but it is very difficult to state in figures. The difference at different times is due to the fact that the snail on to which the chain is wound steadily increases in diameter from one end to the other. It is exactly like a scroll, and not like a parallel chain barrel. For this reason the more revolutions the snail makes, the less does it pay off in each revolution.

During the run in, the bowl W rises over the apex of the copping rail, and then slowly falls until the spindles reach the rollers once again. The winding wire is then close to the apex of the cops, but just as the run in terminates the

sliding piece of the lever L is once more pushed from its place on the bowl Q. As soon as this happens the winding faller wire and the counter faller wire once more assume the positions shown in Figs. 108 and 110.

We have now considered the movement of the rollers, the carriage, the spindles, the winding faller, and the counter faller wire, throughout one complete run out and run in; not with a view to instructing the initiated, but with a view to giving a student some idea of where to look for the controlling mechanism of the various parts. When he has become familiar with these things by reading, and by personal acquaintance of the machinery at work, he may turn to the more abstruse details. These are of almost infinite variety, for the adjustment of the mule is likely to vary with every succeeding lot of yarn which is spun upon it.

A beginner may learn some of the difficulties that beset his path from the abstruse works on mule spinning that abound in the cotton trade; but when all is said and done he will have to use his own brains to overcome the difficulties of draft and twist. Spinning in a machine, where all the drafting is done between the spindle and the roller, needs something that more resembles instinct than mere information. Knowledge is necessary as a basis, but knowledge based on long practical experience must be discreetly used, if the very best results are to be obtained from a woollen mule.

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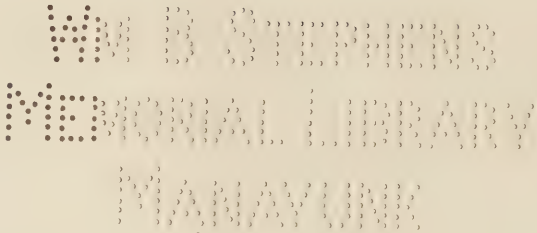
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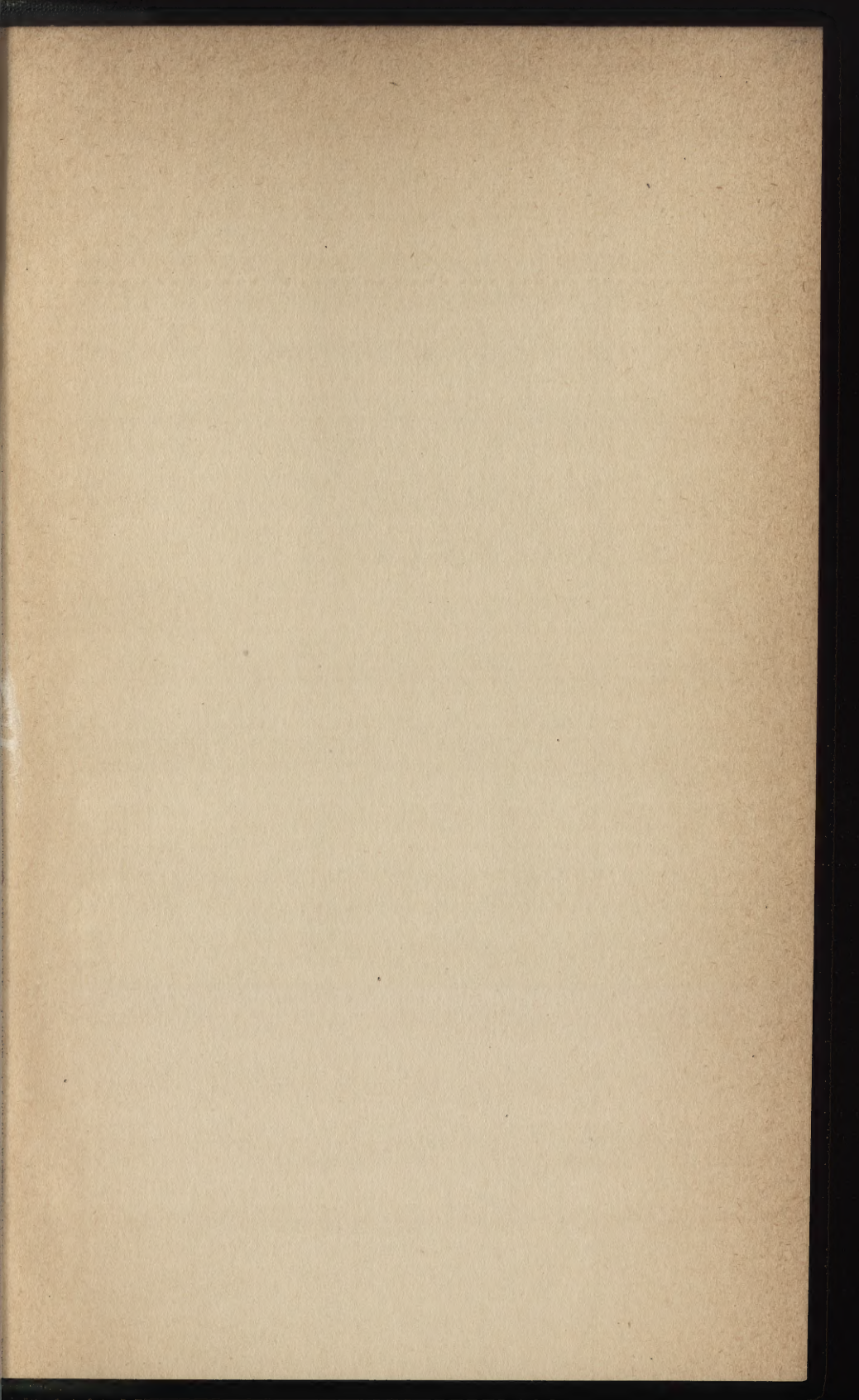
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THE END

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